The
ENGINEERS' DIGEST

A World Review of
DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

VOL. XXI No. 9 SEPTEMBER, 1960

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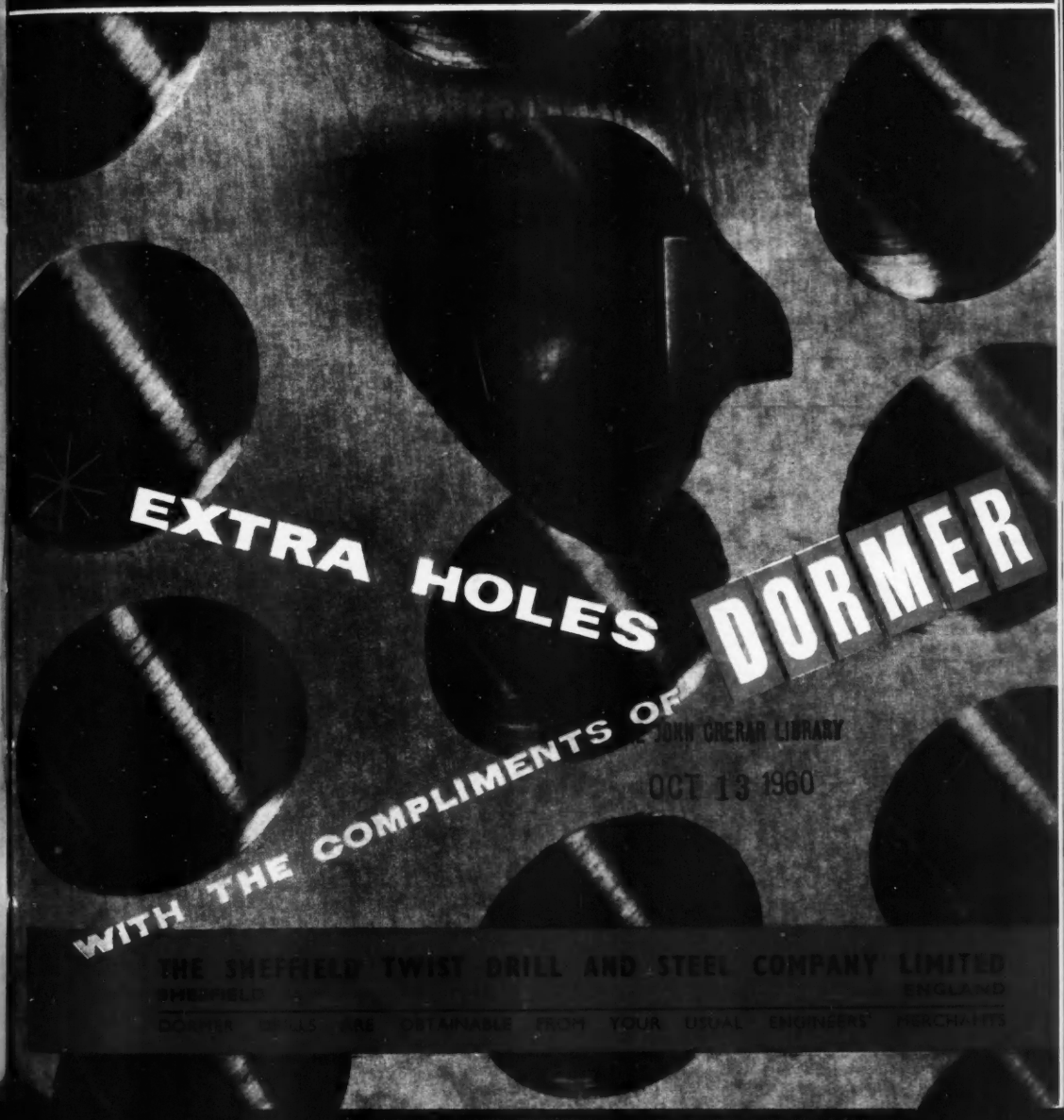
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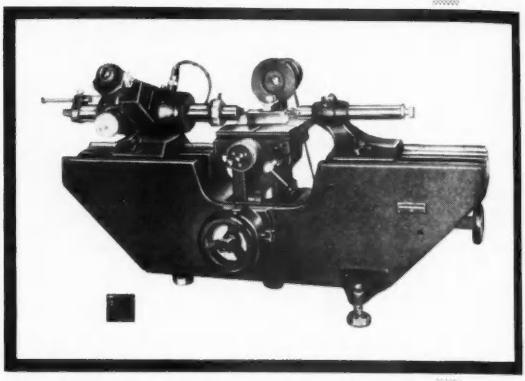

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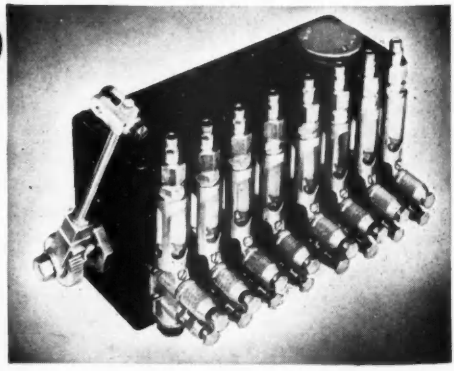

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A World Review of DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

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A brief report in *Product Engineering* (June 27, 1960), indicates that Sylvania Electric Products Inc., of Ipswich, Mass., have developed **compact transformers with a new core design,** in which U-shaped formed metal parts are used in place of laminations of the standard E and I shapes. These U-shaped elements can be nested and stacked in almost any desired configuration, making it possible to design transformers in a wide variety of shapes and in any size up to $18 \times 18 \times 36$ in. Furthermore, these new laminations overcome the problem of interference characterizing the E- and I-lamination alternate stacking system. With the new design, the magnetic lines of force flow with, rather than across, the grain of the steel, resulting in increased magnetic flow. It is this factor which permits weight and size reductions of from 30 to 35%, compared with conventional units.

* * *

Details are given in an article in *Jernkontorets Annaler* (No. 4, 1960) of an **auto-catalytic method of cyanide waste disposal** developed in Sweden, in which additions of ammonium sulphate are made and the solution is kept just below boiling point, neither an oxidizing agent nor the introduction of air being necessary. It is stated that the main advantages of this method are the complete decomposition of the cyanide and the elimination of any need to use special apparatus. The method is specially suitable for the disposal of alkali cyanides, e.g., from heat-treating plant.

* * *

By using a **vapour-growth technique for producing semiconductor devices,** developed in the U.S.A. by International Business Machines, it is believed that the manufacture of semiconductors may be greatly facilitated. In this technique, iodine vapour at a high temperature is used to pick up semiconductor material as a gaseous suspension from a block in the path of the vapour, which then passes to a cooler zone, where the metal deposits on substrate pellets. The amount of impurity introduced by the iodine vapour is stated to be negligible, i.e., about 1 in 100 ppm, and, by repeated runs through the vapour, it is possible to build up a multi-function semiconductor device layer by layer. Thus, various types of diodes, including tunnel diodes and variable-capacitance diodes, and transistors have been produced successfully

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The MINIDIGEST

in this way, and both heterogeneous and homogeneous semiconductor crystals can be formed, while there is no difficulty in depositing silicon of either polarity on silicon, or germanium of either polarity on germanium. Similarly, gallium arsenide and gallium phosphide can be deposited on germanium and, conversely, germanium can be deposited on gallium arsenide, while silicon can be deposited on both gallium arsenide and gallium phosphide.

* * *

It is reported in *Strojirenska Vyroba* for July 1960, that a **high-frequency induction-heating metal-straightening process** is being successfully employed in Czechoslovakia for various machine components, such as gears, which have become distorted during hardening or tempering. In this process, specially designed inductors are applied at selected areas of the distorted component, heating them up and effecting straightening, the heating cycle being followed by quenching in oil or air-cooling. The duration of the straightening process varies from 2 to 20 min, whereas conventional mechanical straightening of analogous components normally takes several hours. Another advantage is that, whereas flame straightening causes comparatively large areas to be heated up, giving rise to stress concentrations and structural changes in the components concerned, the induction-straightening process, owing to the skin effect of the high-frequency current, subjects small areas to high temperatures for very short periods, thereby eliminating the risk of structural changes.

* * *

Unexplained voltages and currents of large magnitude on underground pipelines have long been the subject of investigation and speculation, and are generally referred to vaguely as "anomalous". It would now appear, however, from a recent report in *Corrosion* for August 1960, that a very likely explanation is that there is a definite **correlation between sunspot activity and pipeline voltages.** This explanation is derived from the discovery that, during the intense sunspot activity noted in July 1959, recordings of voltages across an insulating flange on a pipeline showed fluctuations which corresponded very closely with the intensity of sunspot activity, exceeding both the normal positive and negative limits with the onset of sunspot activity. This activity continued for several

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days, during which time similar recordings were obtained, and, after the activity diminished, the voltages returned to their previous value. These phenomena were also noted on other underground structures of unrelated systems and seem to provide ample proof of the true origin of these "anomalous" voltages and currents.

* * *

Bearing in mind that, according to theory, the phenomenon of superconductivity cannot take place at temperatures higher than about —260°C, it would appear that the **possibility of superconductivity in metals at room temperature** is indeed very remote. However, based on indications from an investigator at the R.C.A. research laboratories, it is stated that a superconductive transition could occur at room temperature if the thermal energy which normally destroys the effect could be overcome, and this can be achieved by the use of extremely high current densities, i.e., of the order of 10^9 A/cm^2. Admittedly, this is, in itself, a theoretical concept, and its practical realization is by no means an easy matter. One method of tackling the problem is under consideration and involves current initiation at an extremely high speed, so as to avoid the build-up of heat. A second method of approach envisages short-circuiting a material at its normal superconductive temperature, thus permitting an immediate transition to the high-current superconductive state, which, it is believed, would then be maintained at room temperature.

* * *

A paper in *The Journal of the Institute of Electrical Telecommunication Engineers of Japan* (March 1960) describes a **new type of field-effect transistor,** comprising a grown germanium *p-n* junction, provided with three ohmic contacts, i.e., the source, the drain, and the gate, the highly doped *n*-type side of the transistor representing the gate. It is stated that this new transistor, which is recommended as a switching device, has a pinch voltage of 16 V, a drain current of 1·5 mA, and a frequency of 20 Mcs.

* * *

In a brief report in *Electronics* of July 8, 1960, mention is made of progress in connection with the development of **television tubes with wider deflection angles.** With regard to virtually flat "picture-frame" tubes of the Gabor and Aiken types, and of a third type now under development by R.C.A., it is considered that the

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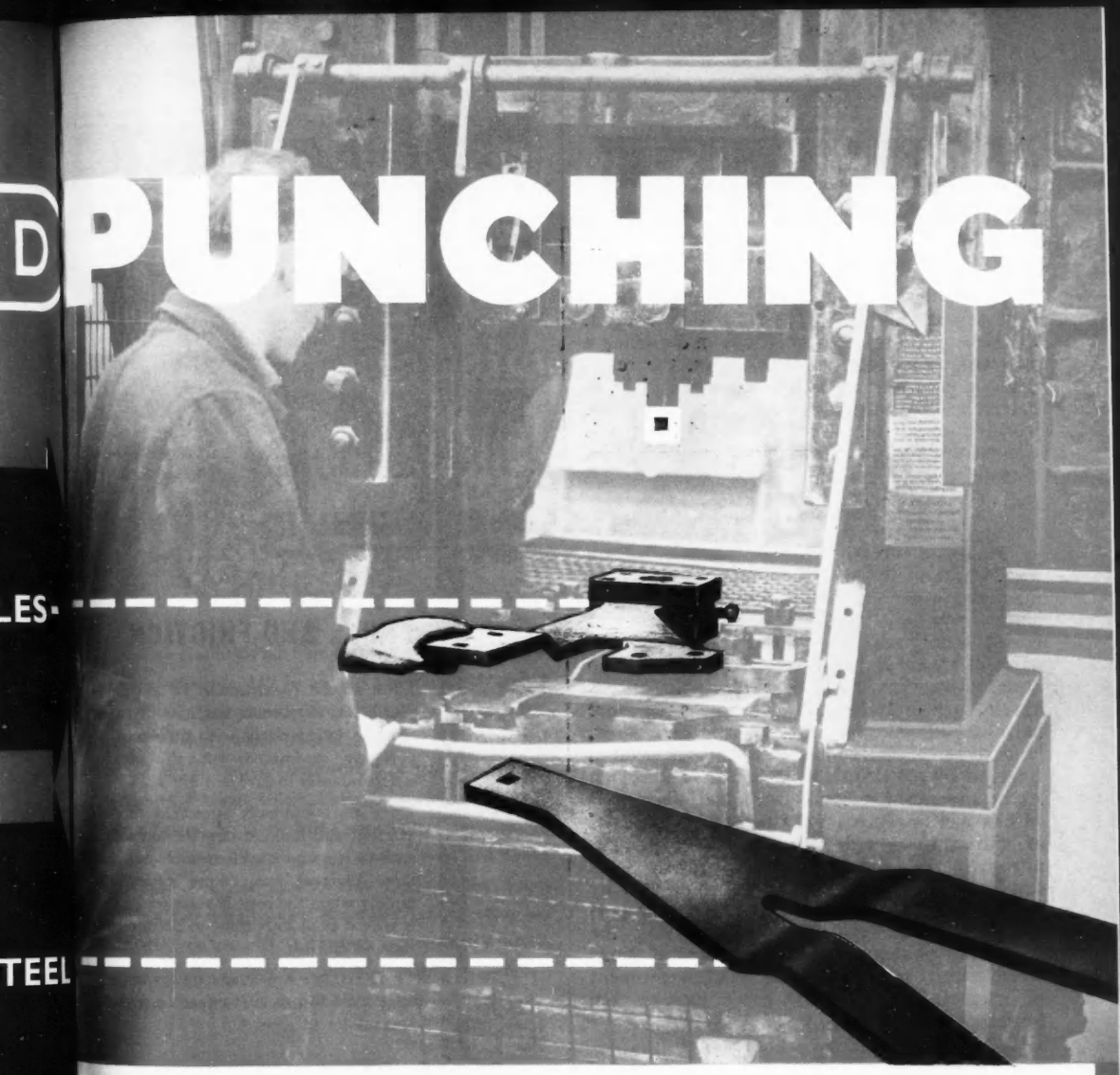

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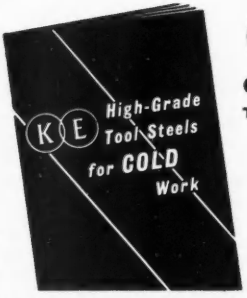

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production of any of these types is at least five years away. Mention is, however, made of a 122-deg. tube developed by Philco. The first model of this tube had an 18-in. screen and an overall depth of $8\frac{7}{8}$ in., its power output being 8 W, as compared with $2\frac{1}{2}$ W for older designs. Considerable work has been done in designing a new yoke and gun for these tubes, the result being a gun only $3\frac{1}{16}$ in. in length and $1\frac{1}{8}$ in. in diameter. The firm is now reported to be working on 21-in. and 24-in. models of this wider-angle tube, in place of the original 18-in. version.

* * *

Magnetic cores are usually made of silicon iron, which can be made into strip with excellent magnetic properties. Unfortunately, these properties may be seriously impaired by impurities in the alloy, and among those known to be harmful are carbon and nitrogen. Although no quantitative data have been available, it has always been considered that carbon is the more harmful of the two in this respect. Now, however, following a series of tests carried out in England by the British Iron and Steel Research Association in connection with the **influence of carbon and nitrogen on the magnetic properties of silicon iron,** it has been established that nitrogen is by far the worse offender. It is considered that there are two mechanisms by which impurities can affect the magnetic properties of silicon iron, i.e., by modifying the crystallization texture, and by forming inclusions which tend to hinder the wall movement of magnetic domains and hence increase the hysteresis loss.

* * *

Details are given in *Materials in Design Engineering* for July 1960, of a new **algae-resistant alloy** developed by the Bridgeport Brass Co., of Bridgeport, Conn., for condenser and heat-exchanger applications where fresh or saline waters support the growth of algae. The alloy has a nominal composition of 70% copper, 30% zinc, and 0·05% mercury, the mercury giving the alloy unusual resistance to dezincification and to fouling by algae, etc., as well as good resistance to other forms of corrosive attack. Tests with this alloy have shown that water-deposited scale is thin and is easily removed by mechanical cleaning, and that a lower concentration or less frequent and shorter periods of chlorination are required to keep the tubes clean.

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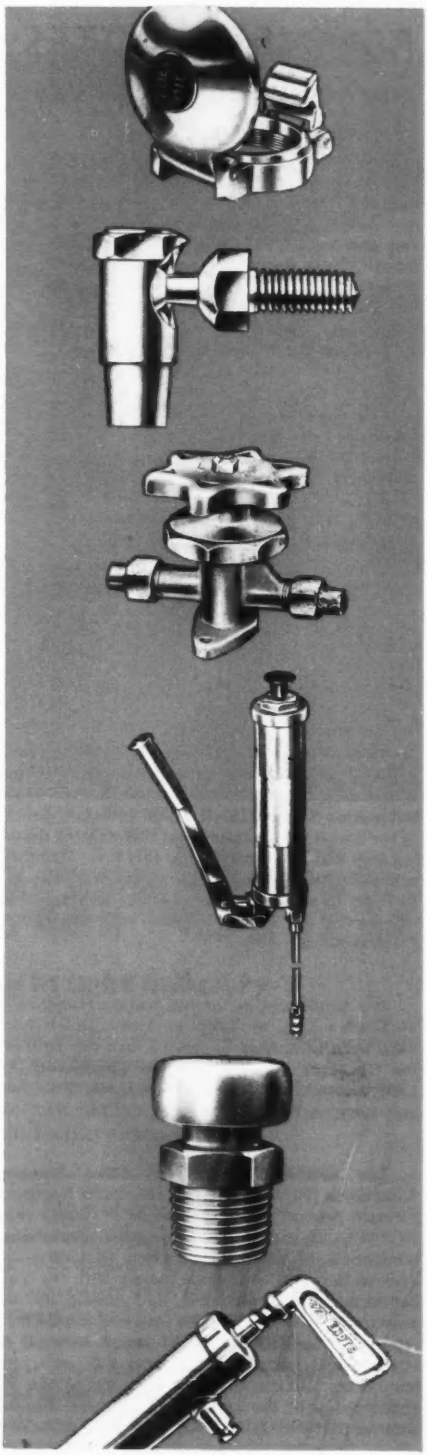

BUSINESS NOTES

A jointly owned sales subsidiary in Canada, to be known as **David Brown-Foote Gears, Ltd.,** has been established by the **Foote Bros. Gear and Machine Corporation,** of Chicago, and **The David Brown Corporation Ltd.,** of London. The new company will take over the sales and distribution in Canada of gear products manufactured by both companies, together with products of **The Whitney Chain Company,** a division of Foote Bros., and will also perform related manufacturing and assembly operations. The headquarters of the new firm will be at 26 Howden Road, Scarborough, Toronto.

* * *

The London press centre of **Associated Electrical Industries Ltd.,** has now moved to their new address at Crown House, Aldwych, London, W.C.2. (Tel: TEMple Bar 8040). Initially, the members of the press centre will comprise Mr. S. White, with Messrs. J. F. Amor and G. A. T. Burdett representing the Manchester and Rugby interests of A.E.I.

* * *

The **Melbro Machine Tool Co. Ltd.,** of Manchester 16, have been granted the sole selling rights through the U.K. for all equipment manufactured by **Peugeot,** including electric drills, drill stands, grinders, portable and stationary saws, routers, and polishers.

* * *

Firth Cleveland Ltd., of London, S.W.1, have acquired **J. J. Habershon & Sons Ltd.,** of Rotherham, rollers of steel strip, from the **Iron & Steel Holding and Realisation Agency** (ISHRA), for £700,000, for the whole of the issued share capital, and £400,000 for the outstanding loan due by Habershon to ISHRA. Habershon have extensive cold-rolling facilities and premises of 375,000 sq ft on 36 acres, and the new acquisition will bring the turnover of the Firth Cleveland steel interests to about £11,000,000 currently.

* * *

It is announced by the Mechanical Handling Division of **Teleflex Ltd.,** of Basildon, Essex, that arrangements have been completed to absorb into the Teleflex Group the **Conveyor Construction and Engineering Company Ltd.,** who will continue to trade under their own name as a member of the Group.

* * *

The **British Electrical & Allied Manufacturers' Association** (BEAMA) has established a Semiconductor-Devices Section, with a view to providing within the BEAMA an expert body to guide manufacturers of semiconductor devices on matters of industrial policy. This section will co-operate closely with the Valve and Semiconductor Association, and among its important objectives will be the work of fostering standardization of semiconductor devices, both on a national and an international basis. The section will also co-operate with other associations and sections of the BEAMA concerned with the application of these devices, while commercial and contractual matters, including those arising from the operation of the European Community Treaty and the agreement with the E.F.T.A. countries, will be studied, together with matters affecting tariffs, import duties, etc. The chairman of the new section is Mr. L. E. Thomson, director and manager of the Rectifier Section of the Westinghouse Brake & Signal Co., Ltd. The secretary is Mr. C. Brooks, BEAMA, The Red House, Ascot, Berks. (Tel: Ascot 1960), from whom further information can be obtained.

* * *

Drabble and Sanderson Ltd., of Sheffield, have been appointed sole agents in the U.K. for the sale of the carbide-tipped circular saws manufactured in the U.S.A. by the **American Saw and Tool Company,** of Louisville.

* * *

With a view to eliminating overlapping interests and to facilitate closer co-operation between research, development, and production, **Gresham Developments, Ltd.,** of Hanworth, Middlesex, and **Lion Electronic Developments, Ltd.,** of Feltham, Middlesex, have been amalgamated to form a new company, **Gresham-Lion Electronics, Ltd.,** of Gresham House, Twickenham Road, Hanworth (Tel.: FELtham 2271).

* * *

The **Mortimer Engineering Company** has been acquired by **B. Elliott & Co. Ltd.,** and will in future trade as the **Mortimer Engineering Co. Ltd.** This acquisition will operate under the direct control of its new executive directors, i.e., Mr. E. W. Kelleher (managing director) and Mr. F. E. Wilson (director).

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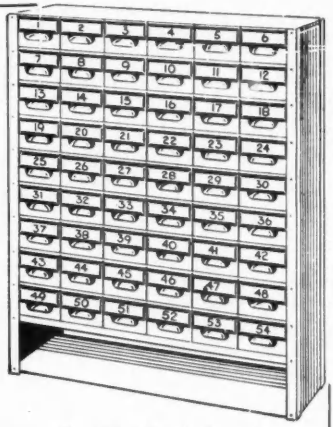

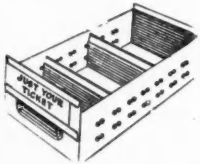

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PERSONAL

Mr. A. H. Freeman, A.M.I.Mech.E., A.M.I.C.E., has been elected chairman and managing director of Heatrae Limited, of Norwich, Norfolk.

* * *

Mr. R. Foxwell, managing director of Wayne Kerr Laboratories Ltd., has been elected to the council of the Scientific Instrument Manufacturers Association. Mr. Foxwell, in association with **Mr. R. Calvert,** then of the B.B.C. Research Department, founded Wayne Kerr in 1945.

* * *

At a recent meeting of the Council of The Iron and Steel Institute, **Sir Charles Goodeve, O.B.E., D.Sc., F.R.S.,** was proposed for nomination as President-Elect of the Institute, and will succeed **Mr. W. F. Cartwright** as President at the annual general meeting to be held in May, 1961.

* * *

It is announced by Edgar Allen & Co. Ltd., of Sheffield, that **Mr. W. H. Everard,** deputy general manager of the Foundry Division of the company, has been elected President of the British Electric Steel Makers' Guild.

* * *

Mr. G. R. Shotton, managing director of Shotton Bros. Ltd., of Oldbury, one of the Birfield Group of companies, has been elected President of the Institute of British Foundrymen for the year 1960-61.

* * *

Mr. F. H. Schroeder, M.I.Mech.E., A.M.I.E.E., has been appointed to the Board of Metal Industries Ltd. For many years, Mr. Schroeder has been a director of Lancashire Dynamo Holdings Ltd., which recently became part of the Metal Industries Group.

* * *

Mr. W. E. Duckworth, M.A. (Cantab), A.I.M., has been appointed head of the Metallurgy (General) Division of the British Iron and Steel Research Association. **Professor G. Wesley Austin, O.B.E., M.Sc., F.I.M.,** will continue to act as consultant to the Division.

* * *

Mr. L. P. Simpson, works manager of Baker Perkins Ltd., of Peterborough, has been appointed a director of the company. Mr. Simpson is a member of the council of the Institution of Production Engineers.

* * *

It is announced by The British Internal Combustion Engine Research Association, of Slough, Bucks, that the **Rt. Hon. the Viscount Falmouth, M.I.Mech.E.,** has been re-elected President of the Association, and that the following have been re-elected Vice-Presidents:— **Sir Harold Roxbee Cox, D.Sc., Ph.D., D.I.C., M.I.Mech.E.; Rear-Admiral W. F. B. Lane, C.B., D.S.C., M.I.Mech.E., M.I.Mar.E.,** Director of Marine

NEW

worm drive hydraulic pump

incorporating many interesting features

This pump is specifically designed as a mining hydraulic pump and incorporates many features based on our long experience of mining duties. In particular we would mention—

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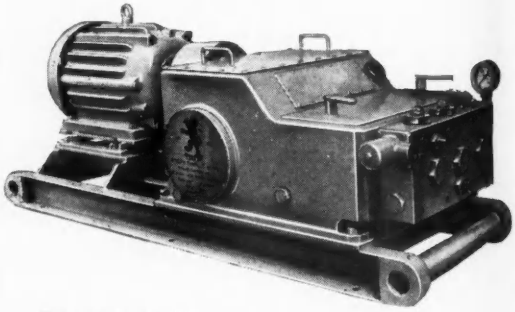
- *EASE OF DISMANTLING*



The unit is suitable for operation with water, water/soluble oil mixture and hydraulic oil.

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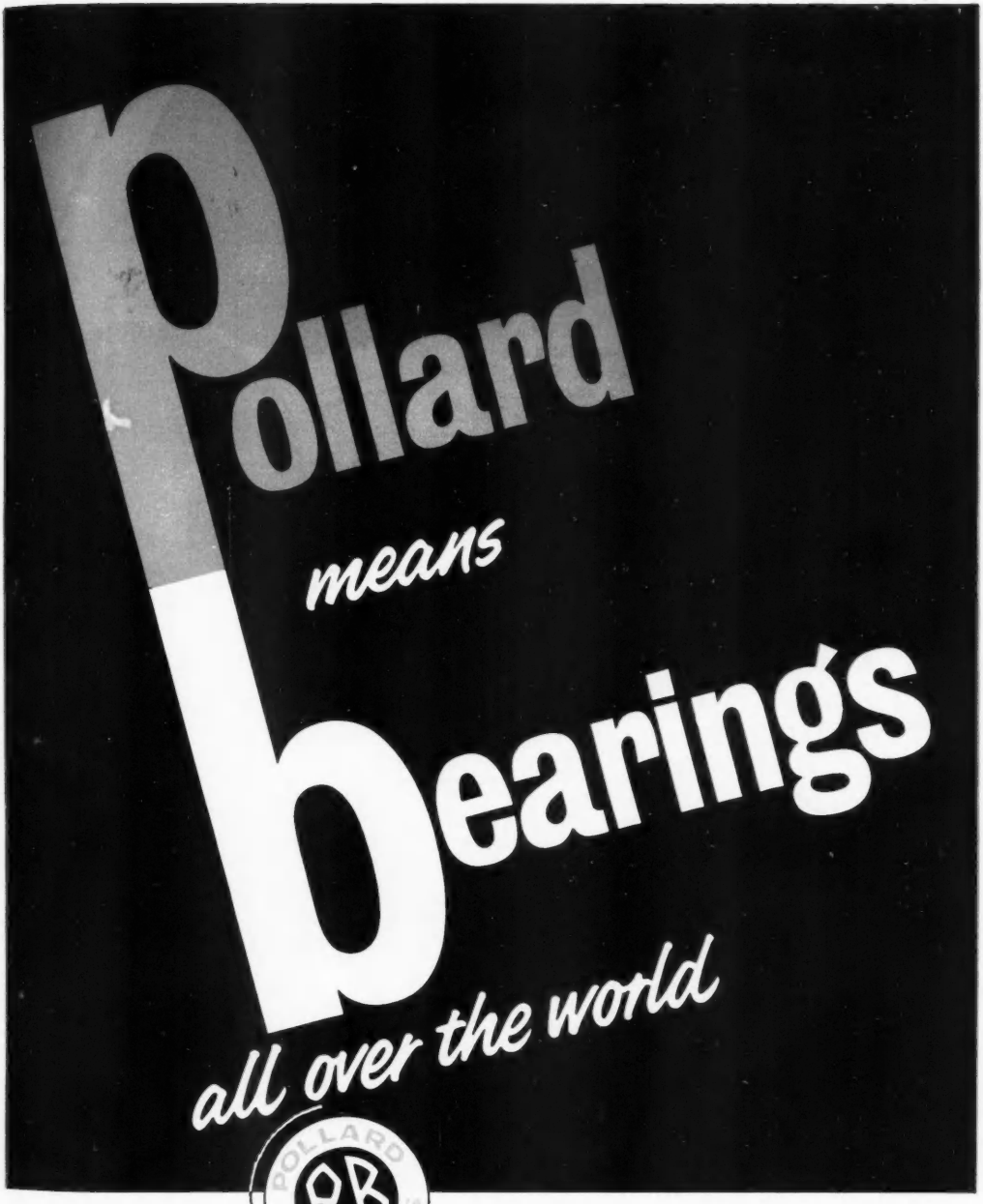

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PERSONAL

Engineering, Admiralty; **Mr. H. N. Pemberton, M.I.Mech.E.,** Chief Engineer Surveyor, Lloyd's Register of Shipping; and **Brigadier J. T. S. Tutton, O.B.E.,** Director, Royal Engineer Equipment, War Office. A newly elected Vice-President is **Professor S. J. Davies, C.B.E., D.Sc.(Eng.) Ph.D., M.I.Mech.E.**

* * *

It is announced by Associated Electrical Industries Ltd. that, following his appointment as the first High Commissioner in the Federation of Nigeria, the **Rt. Hon. the Viscount Head of Throope, P.C., C.B.E., M.C.,** has resigned from the board of directors. **Sir Joseph Latham, C.B.E.,** has been elected a director, while **Mr. C. R. Wheeler, C.B.E.,** has been appointed an additional vice-chairman of A.E.I. and will take up executive duties in 1962.

* * *

Mr. J. E. Yates has been appointed general sales manager of Lancashire Dynamo & Crypto Ltd., a company in the Metal Industries Group, and will be based at the company's Trafford Park works. **Mr. H. G. Boullen** remains sales director, operating from London.

* * *

B. P. S. Machinery & Spares Co. Ltd., of London, S.W.7, announce the appointment of **Mr. D. J. Parsons,** of 91 Hilton Road, Bishopbriggs, Lanarkshire (Tel.: Bishopbriggs 1452) as their sales engineer representative for Scotland and the Tees and Tyne areas.

* * *

Mr. W. J. Fry, A.M.Brit.I.R.E., a director of Solartron Research & Development, Ltd., has been appointed sales director and commercial manager of Solartron-John Brown Automation, Ltd., of London, W.2.

* * *

The Castrol Group announces the appointment of **Messrs. J. Romney, N. E. F. Hitchcock** and **G. H. J. Simmons,** all senior executives of the Castrol Research and Technical Departments, as directors of the board of their subsidiary company, Edwin Cooper & Company Ltd.

* * *

It is announced by the British Iron and Steel Research Association (BISRA) that **Mr. J. F. Stanners, B.Sc.,** has succeeded **Dr. J. C. Hudson,** who has retired as head of corrosion research in the Chemistry Department of BISRA. **Mr. E. E. White, F.R.I.C., A.M.I.M.M., F.Z.S., M.I.Inf.Sc.,** has been appointed head of the BISRA Corrosion Advice Bureau.

* * *

The Fafnir Bearing Co. Ltd., of Wolverhampton, announce that **Mr. G. H. Marchant** (general manager) has been elected to the board of the company, assuming the title of director and general manager.

First the billet...

Oxy-acetylene rail re-surfacing on Snowdon's Mountain Railway (With acknowledgements to British Oxygen Gases Ltd.)

CTCO

WINGS DAY SEPT. 17th

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50 lbs. lightweight cylinder mounted on Kidde Model T.50 Fire Extinguisher Truck Unit (With acknowledgements to the Walter Kidde Company Ltd.)

then the cylinder

Many are the end uses for Chesterfield seamless steel gas cylinders; nearly 9,000,000 manufactured to date, pierced and drawn from solid billets of steel. Cold drawn seamless steel Chesterfield cylinders are produced to conform to the specifications and regulations ruling in all countries, and are as perfect as our modern plant and manufacturing "know-how" can make them.

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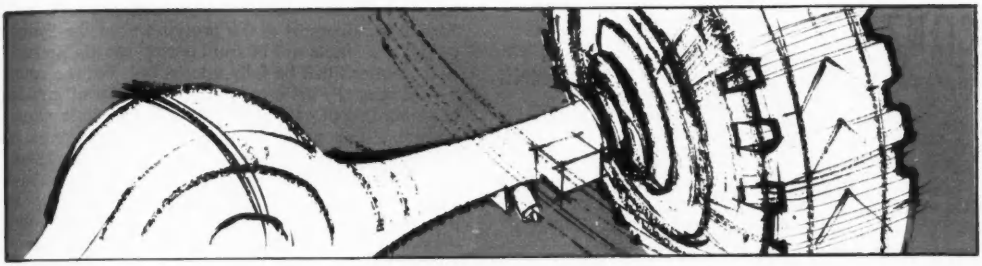
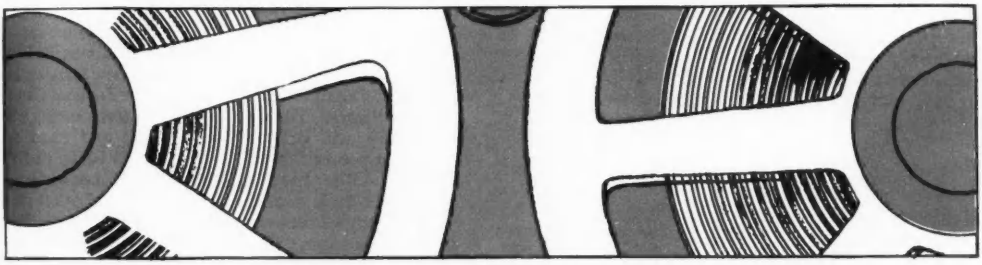
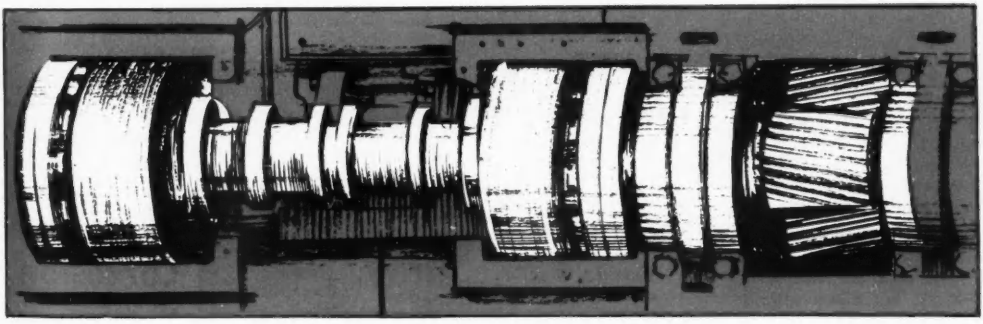


consult R&M bearing experts



when at the prototype stage



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CONTRACTS

A £610,000 contract for cross-Channel power cables has been placed by the Central Electricity Generating Board with Associated Electrical Industries Ltd. and British Insulated Callender's Cables Ltd., who will lay half of the cross-Channel submarine power-cable link which will connect the national electricity systems of Britain and France. The other half will be laid by cable-making companies appointed by Electricité de France. The contract calls for the manufacture and laying of two similar 15-mile lengths of single-core submarine cable and two related land cables, the work being divided equally between B.I.C.C. and A.E.I. The cables must be laid close enough to one another on the sea bed to conform with the Minister of Transport's requirement that at all times the magnetic-compass deflection caused by the cables does not exceed 2 deg. at the sea surface.

* * *

The Electricity Department of the Qatar Government has placed an order with The General Electric Co. Ltd., of England for two 15-MW single pass-out turbo-generators for installation in the Ras Abu Aboud power station. The order, which is valued at nearly £700,000, includes the condensing plant and boiler feed pumps, together with the cranes, compressed-air system, and the air-conditioning and ventilation plant for the station. The new turbo-generators, which will be suitable for operating in parallel with five 2600-kW, 11-kV diesel generating sets already installed, are rated at 11 kV, 15 MW, 50 cps, with turbine stop-valve steam conditions of 600 psig and 850° F. The pass-out steam is to be used for the distillation of sea water to produce drinking water, some 110,000 lb/hr of steam at 12 psig being bled off. The turbines exhaust at 27½-in. vacuum. Delivery of the first set is scheduled for December, 1961, and of the second set for March, 1962. The consulting engineers for the project are Preece, Cardew and Rider.

* * *

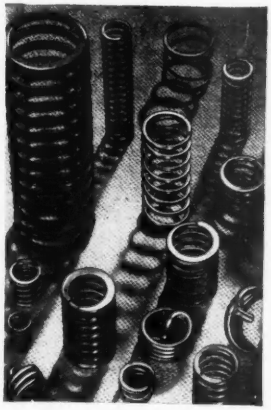
An order for automatic control equipment, valued at £90,000, for a new zinc-smelting plant to be erected at Noyelles-Godault in Northern France has been placed with the Industrial Weighing Division of Elliott Brothers (London) Limited, a member of the Elliott Automation Group.

* * *

A £250,000 contract for three horizontal extrusion presses has been awarded to Fielding & Platt Ltd., of Gloucester, by Aluminium Menziken AG., of Switzerland. These Fielding presses, ranging in power from 750 to 1500 tons, will each be operated from an independent hydraulic system, powered by a battery of high-speed, motor-driven oil pumps working at pressures up to 2 tsi. The 750-ton press is designed chiefly for the extrusion of aluminium and aluminium-alloy rods and solid sections. The two larger machines, in addition to carrying out this type of work, will also be capable of producing tubes and hollow sections from pre-drilled or solid billets up to 8¾ in. in diameter by 27½ in. in length. All three presses will incorporate a number of special features, some of them developed by Fielding & Platt, while others will be based on the extensive experience of Aluminium Menziken. Control of the presses and of the hydraulic circuit as a whole will be from central control desks. All press motions will be fully interlocked, but the controls will be specially arranged to give a choice of individual hand control of each motion or of automatic sequence control. The presses and their controls have been designed for operation with the absolute minimum of labour, and special attention has been paid to the die-changing facilities in order to cut down the non-productive time in each press cycle. A further feature is the provision of electrically heated die-holders for maintaining the die temperature, not only during actual extrusion, but also when the die is in the "out" or "waiting" position.

* * *

The most powerful diesel-electric propulsion installation ever ordered in the U.K., costing about £400,000, will be built by English Electric for the new ferry ordered from Wm. Denny & Brothers by the New Zealand Government Railways. This new 4000-ton vessel, costing about £1,700,000, will be a "drive-on" rail and road ferry operating between the North and South islands of New Zealand. The propulsion machinery comprises six 16-cylinder main engines, giving a total of 9000 shp to the twin propellers, and will be controlled on the Ward-Leonard principle. The auxiliary installation is supplied by three 450-kW diesel-alternator sets, each powered by a 6-cylinder engine, the working parts of which are largely interchangeable with those of the main engines. The installation will be engineered by English Electric's marine department at Rugby.



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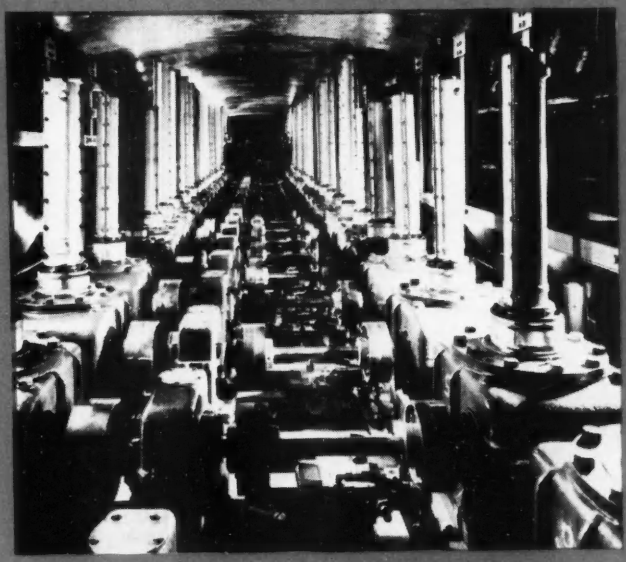
BIG JOBS

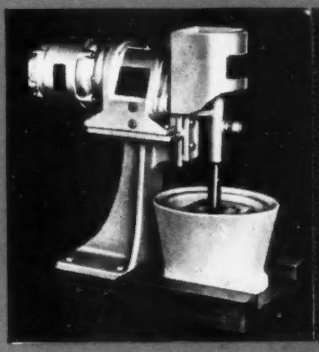
-such as supplying many special worm reduction gear units to the Royal Aeronautical Establishment for the supersonic wind tunnel at Bedford are not new to us here at Newbury, for besides non-standard units, our normal range of worm and spur units covers practically all industrial applications up to 120 h.p.



Type WGV 51 single reduction worm gearbox driven by WGV 41 single reduction gearbox. As supplied to the Royal Aeronautical establishment, Bedford, for use in the 8ft. supersonic wind tunnel. The photograph shows part of the assembly of the working section of the tunnel.

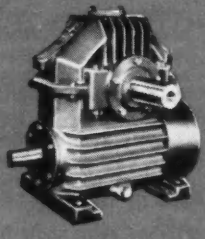
AND SMALL JOBS

-such as the production of a small gear unit for an experimental pan and muller for grinding colours is another example of our standard range. Our compact, robust helical and spur geared motors are available as double or triple reduction units in six sizes, offering a complete range of horsepowers and output speeds to the user. You can't go wrong if you specify—



Laboratory colour Pan driven by a ¼ h.p. drip proof geared motor unit. Type S.G M.1 Ratio 22 : 1. Output speed 63 r.p.m. This photograph is reproduced by permission of William Boulton Ltd Burslem, Staffs.

Type SUH horizontal shaft, fan cooled worm reduction gear. Standard sizes up to 12 in. centres; non-standard sizes up to 24 in. centres. Ratios 3:1 to 100:1.



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NEWS ROUND-UP

Combustion Engineering Association Conference

A conference will be held by The Combustion Engineering Association at the Hotel Majestic, Harrogate, on November 8 and 9, 1960, to assist industrial management and plant engineers in choosing the best coal and plant for their particular requirements. The conference will examine, from both the technical and economic aspects, the choice of coal allied to the selection, operation, and maintenance of equipment for boiler plant and industrial furnaces and kilns, in order to achieve the maximum possible savings in capital and operating costs.

The conference will be open to non-members of the Association, and full details can be obtained from the Director, The Combustion Engineering Association, 70 Jermyn Street, London, S.W.1.

Symposium on Batteries

Following the success of the Battery Symposium held in 1958, the Inter-Departmental Committee on Batteries has undertaken to hold a similar symposium at intervals of two years. The second symposium will be held from October 18 to 20, 1960, at The Pavilion, Bournemouth, when some 25 papers will be presented, covering a wide field of subjects concerned with research, development, and applications of battery systems. The symposium will be attended by manufacturers and users both from the U.K. and overseas.

Further information can be obtained from Mr. F. C. Wells, Ministry of Aviation, S.R.D.E., Christchurch, Hants.

Joint British Committee for Stress Analysis

It is announced by The Institution of Mechanical Engineers, London, that, following an exploratory meeting held on March 1, 1960, arranged by The Institute of Physics, a Joint British Committee for Stress Analysis has been set up in Great Britain. This committee will represent the interests of Great Britain in the field of stress analysis at the periodic meetings of the Permanent Committee held in Europe and will thus ensure adequate British participation in international conferences in the field of stress analysis.

The principal object of the Permanent Committee, membership of which is open to all West-European countries, is the furtherance of international collaboration in connection with stress analysis and, with a view to achieving this collaboration, international conferences will be arranged at intervals of four years, these conferences normally being phased with the international congresses on applied mechanics. The officials and secretariat of the Permanent Committee will normally be appointed by the National Committee in whose country the next international conference is due to be held.

The objectives of the Joint British Committee for Stress Analysis will be to act in the collective interest of the constituent bodies by maintaining liaison with the Permanent Committee for European or international conferences on stress analysis, and by maintaining liaison with overseas societies and institutions concerned

Think of speed . . .

Think of safety . . .

There is an element of risk in the use of all man's contrivances, but it is usually quite insignificant. That is because we have come to rely on the components used; to take for granted that they will never fail us.

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The use of SuPerfect seals on disc brakes of high speed passenger carrying vehicles is proof of confidence in our components.

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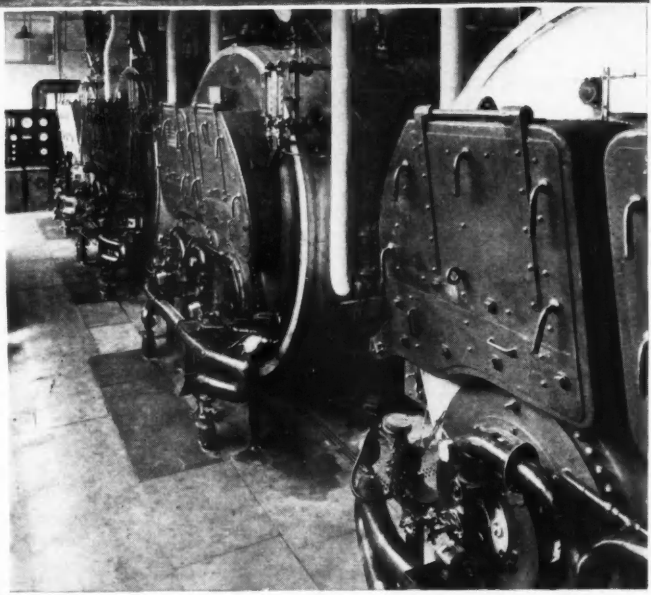
Photos by courtesy of Queen Mary's (Roehampton) Hospital. Boiler plant includes four Marshall Three-pass Economic boilers each fired with two Rotavac No. 3 WSF Burners.



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Hospital service calls for the utmost in efficiency and reliability—service that the world of public undertakings and industry has learnt to expect from Rotavac oil-firing. Rotavac provides high efficiency atomisation with minimum maintenance (no moving parts), perfect flame form, automatic control and the economy of the cheapest liquid fuels. Backed by nation-wide spares and after sales service.

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NEWS ROUND-UP

with stress analysis. The Joint British Committee consists of representatives appointed by The Royal Aeronautical Society, The Institution of Civil Engineers, The Institution of Electrical Engineers, The Institute of Marine Engineers, The Institution of Mechanical Engineers, The Royal Institution of Naval Architects, The Institute of Physics and The Physical Society, The Institution of Structural Engineers, and The Institute of Welding.

Mr. A. F. C. Brown, of the National Physical Laboratory, and the representative of The Institution of Mechanical Engineers, has been elected the first chairman of the committee, and The Institution of Mechanical Engineers is to provide the secretariat for the committee.

Design-Appreciation Course for Engineers

The Council of Industrial Design is arranging a course in design appreciation for apprentices and junior engineers from both the light- and heavy-engineering industries. It will be held near London in November and December, and will be arranged in two residential periods, each of four days, separated by an individual study period of three weeks, the cost being 35 guineas for each student. A detailed programme is now being prepared and will be available shortly.

Obviously, it is not the aim to attempt to teach industrial design in so short a time, but rather to make members aware of design, first in its widest context in the domestic, public, and industrial fields. Then, the design of particular products will be examined in detail to develop analytical abilities of students, who finally will be required to make recommendations for improving the design of selected goods. The exact form of the courses will naturally depend on the age of the members, the type of engineering industry, and the periods most suitable for those who can join, but the factor common to all is the development of design awareness. Students will also be able to discuss the analyses and their suggested design improvements with the industrial officers of the Council of Industrial Research.

Those interested should apply for further information or enrolment as soon as possible to the Education Section of the Council of Industrial Design, The Design Centre, 28 Haymarket, London, S.W.1.

The International Plastics Exhibition

"Interplas 61", the sixth International Plastics Exhibition and Convention, will be held at Olympia, London, from June 21 to July 1, 1961, and will have a total floor space for exhibitors of more than 300,000 sq ft. The Exhibition, organized by "British Plastics", will once again cover all aspects of the industry, including basic and semi-processed materials, finished products, industrial components, and processing machinery and accessories. Fully representative displays are expected from all major countries which are active in this field, including France, Germany, Italy, the Netherlands, Switzerland, and the U.S.A., as well as the U.K.

Full details can be obtained from the organizer, Mr. John L. Wood, Dorset House, Stamford Street, London, S.E.1.

TEAM WORK—

It's team work that counts . . . .

. . . team work all the way through, from the inception to the finishing processes. In all the intermediate stages of your production, Weathershields can help you by co-operation in design, development, manufacture and service, to solve your bottle-neck problems and maintain maximum output.

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PATENTS FOR SALE

Patent No: 804,376 entitled "Method of and apparatus for making Abrasive Tools" is for sale or licence. For details apply to CHATWIN & COMPANY, Chartered Patent Agents, 253, Grays' Inn Road, London, W.C.1.

SITUATIONS VACANT

DEVELOPMENT ENGINEERS AND TECHNICAL ASSISTANTS

are required by the United Kingdom Atomic Energy Authority at Dounreay, Experimental Reactor Establishment, Thurso, Caithness, to work in a group which is engaged on development in all fields of engineering; to assist with the operation of the fast reactor and in developing and carrying out experiments to enable information to be obtained from the reactor.

Applicants should have served a recognised engineering apprenticeship and be corporate members of the Institute of Mechanical Engineers, or have equivalent qualifications. Alternatively, candidates with a degree in mechanical engineering who have served a recognised engineering apprenticeship and who wish to extend their post-graduate experience may be considered for posts as Technical Assistants and trained to take up posts as engineers.

Salaries: Engineers £860 (at age 25)—£1,175 (at age 34 or over) —£1,340.
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Contributory superannuation. Staff housing scheme.
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NEW 200-TONS PRESS BRAKE. IMMEDIATE DELIVERY, subject to prior sale. Thickness formed $\frac{1}{4}$ in. × 167 in. over 2 in. die opening. Maximum working length 13 ft. 11 in. Between uprights 11 ft. 8 in. Steel plate construction. Motor drive. Weight about $25\frac{1}{2}$ tons. An excellent machine.

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METALS DIVISION — RESEARCH

A

MECHANICAL ENGINEER

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NEW TECHNICAL BOOKS

Practical Welding Repairs. By C. G. Bainbridge, M.I.Mech.E. 132 pp., 35 illustrations. Publishers: Temple Press Limited, Bowling Green Lane, London, E.C.1. Price 15/–.

Dealing with the application of oxy-acetylene and arc welding to general repair and maintenance work, this excellent book is not fundamentally intended to teach welding, but rather to describe the application of welding to the repair of sheet metals and castings, and to the reclamation and maintenance of wearing parts. As such, it is written essentially for repair welders and covers welding-repair applications over a wide range of industry.

Bearing in mind that repair welders often work under greater difficulties than production welders, particularly in not knowing beforehand the weldability of the metal they are called upon to deal with, the book includes a review of the welding behaviour of typical metals and alloys. Actual jobs have been used as the basis of descriptions of the applications of successful procedures and methods, and the book is altogether a comprehensive and practical work containing all the information and guidance needed by repair welders to improve their technique and to apply it most effectively to any of the tasks coming within the wide scope of general repair welding.

Broaching. By C. Monday. 158 pp., 154 illustrations. Publishers: The Machinery Publishing Co., Ltd., National House, 21 West Street, Brighton 1. Price 18/6.

Although broaching is not a new method of machining, it has undergone considerable development during recent years and now ranks as a major production process. This new book, still another in the popular Standard Reference Series published by *Machinery*, therefore fills a requirement by showing the working of modern broaching machines and giving details of some of the specialized cutting tools associated with them for internal and surface broaching. As with all books in the Series, this new volume is impeccably produced and is enlivened by a wealth of excellent illustrations.

Since each set-up for broaching is closely related to the type of component required, much of the book consists of examples taken from practice followed in modern factories concerned with the making of parts on both continuous-flow and medium-lot production.

Russian-English Metals & Machines Dictionary. By Dr. Eugene A. Carpovich. 112 pages. Publishers: Technical Dictionaries Co., Box 144, New York 31, N.Y., U.S.A. Price: $9.00.

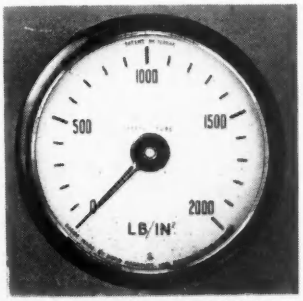
Comprising more than 8000 Russian entries, this useful dictionary, which is based on modern and reliable primary sources in both Russian and English, is designed to cater for the requirements of scientists, research workers, engineers, technical editors, librarians, students, translators, and others whose work deals with Russian publications in the fields of metallurgy and metalworking. All Russian entries are arranged in a single alphabetical list in such a way that it is necessary to open the dictionary only once to find any required entry.

Basically, the dictionary has been divided into four main sections, i.e., metallurgy, metals and alloys, metalworking, and machines. The section on metallurgy includes metallurgical engineering and covers ferrous metals, non-ferrous metals and alloys, steelmaking, rolling, foundry work, welding, powder metallurgy, etc., while the section on metals and alloys includes their molecular structure and physical properties, hardening, and heat treatment. The section on cold and hot metalworking includes forging, bending, drawing, extruding, pressing, spinning, etc., while the section on machines and machining includes turning, milling, planing, broaching, grinding, polishing, and lapping. In addition, machine elements, various tools, manufacturing processes, and hydrometallurgy are covered, together with Russian transliteration of Western names frequently encountered in metallurgical publications, abbreviations, and a selection of Russian shop slang.

Infrared Radiation. By Henry L. Hackforth. 315 pp., 172 illustrations. Publishers: McGraw-Hill Publishing Company Ltd., McGraw-Hill House, 95 Farringdon Street, London, E.C.4. Price: 77/6.

Showing precisely what infrared radiation is, what it does, and how it is used, yet using a minimum of mathematics, this outstanding reference and guide to the subject of infrared radiation as a whole brings together all relevant information on the components and laws of physics involved in their operation, sources of radiation, methods of transmission, and the analysis and design of systems. Though basic in content, the book is broad in scope, presenting the latest material on artificial sources of infrared radiation, and providing a complete picture of the role of this new technology in medicine, optics, astronomy, geophysics, space science, meteorology, biology, spectroscopy, and many other fields, as well as exploring its future and discussing its virtually unlimited possibilities.

By means of numerous clear illustrations and practical examples, a clear understanding of the subject is given, aided by the development of a generalized infrared system, in which the changes undergone by a signal from its source to the final display are shown step by step, together with a detailed description of the "building blocks" used in the model system.



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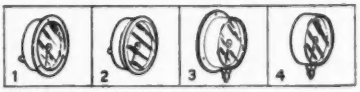

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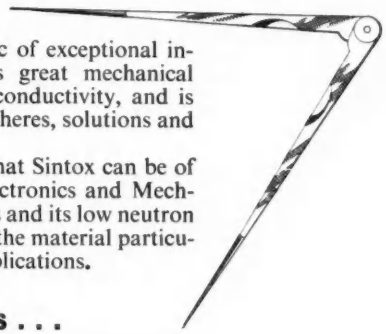

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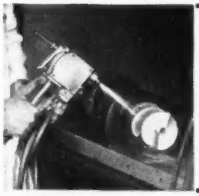

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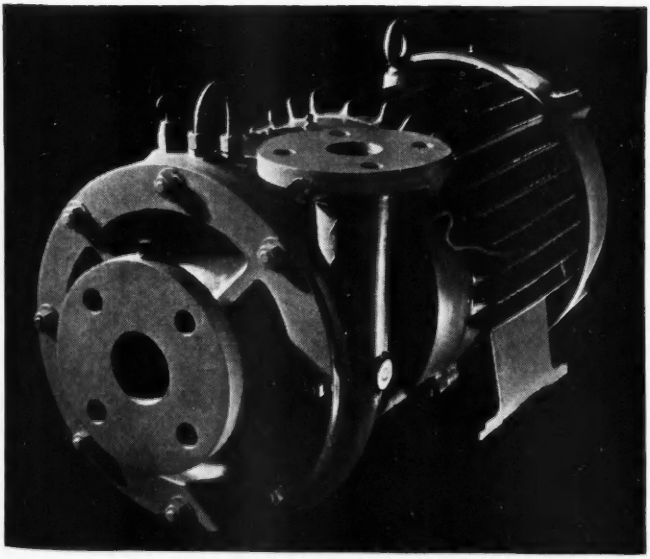

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Particulars are contained in an illustrated 24-page brochure of a range of hydraulic cylinders, such as rod-end and circular flange-mounted cylinders, rod-end, centre, and blank-end trunnion-mounted cylinders, etc. Details are also given of a number of accessories, mounting arrangements, and cushioning, and nomograms and data sheets for hydraulic design are also included. A supplementary 12-page brochure contains information on hydraulic workholders, such as tailstocks, chucks, and vices, and describes numerous applications of hydraulic workholding.

8. Heat-Treatment Furnaces

An illustrated 16-page brochure gives details of operation and applications of a range of heat-treatment furnaces, such as muffle furnaces, cyclone furnaces, salt-bath furnaces, closed-quench furnaces, etc. The furnaces can be employed in a variety of heat-treatment processes, including hardening, tempering, annealing, carburising, vacuum and isothermal heat treatment, and vitreous enamelling. Details are also given of a charging machine, which reduces operating time and simplifies furnace loading, and of a range of atmosphere generators, such as ammonia crackers and liquid-hydrocarbon units.

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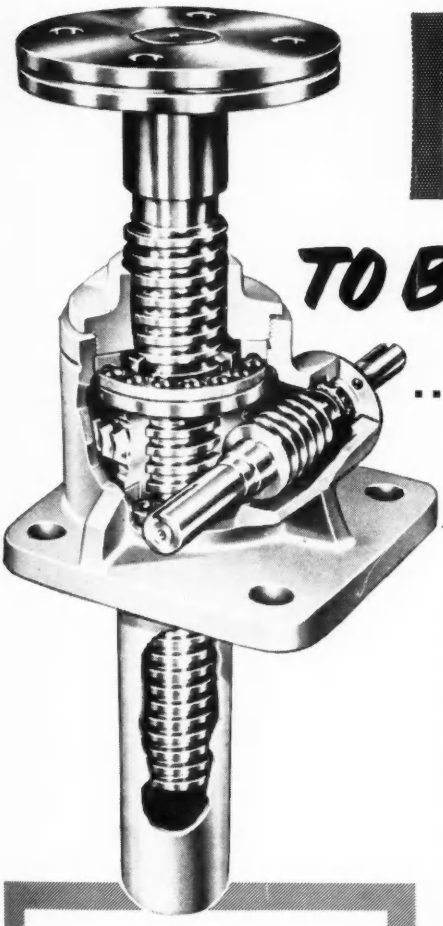
12. Liquid Meters

Eminently suitable for measuring the flow of water, oil, acids, paraffin, glycerine, and a variety of other chemicals and industrial liquids, a range of liquid meters is presented in a 4-page brochure. Maximum line pressures of 150 psi can be recorded by all standard meters, while higher readings can also be obtained by the use of meters of increased size and capacity. A description is also given of a strainer which protects the metres from abrasion or choking by grit, scale, etc.



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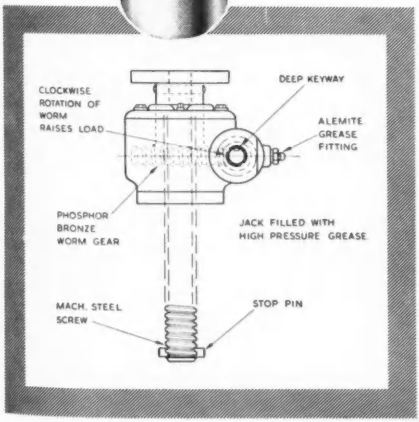

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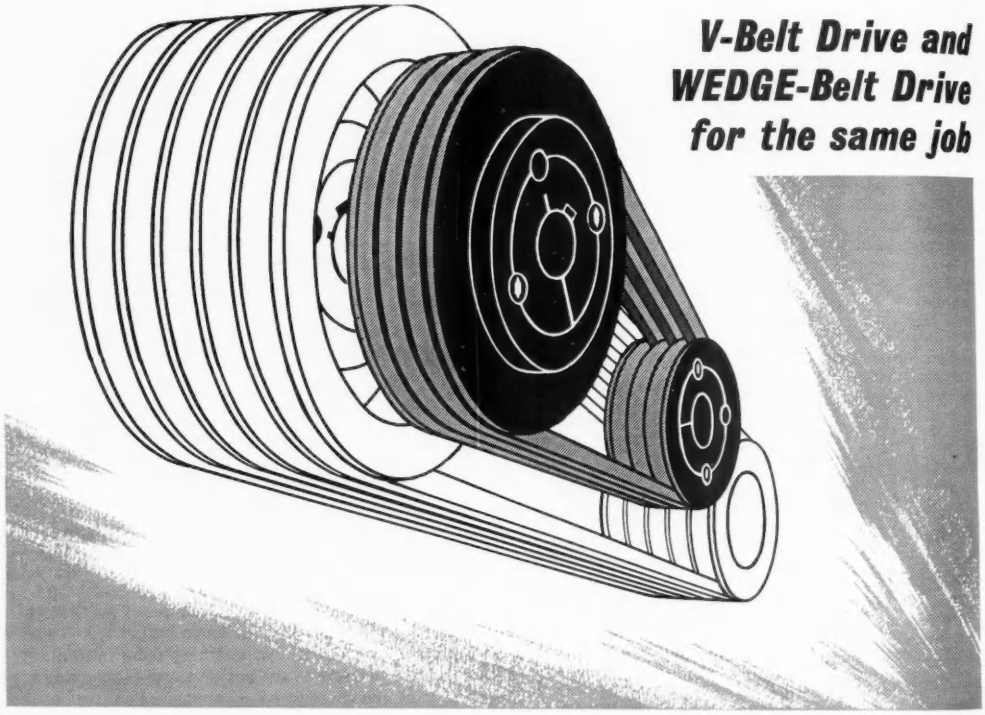

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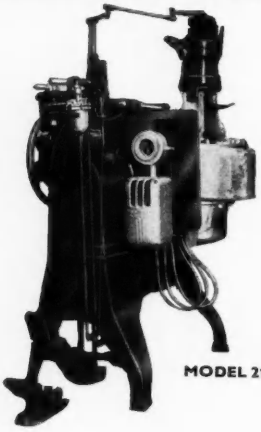

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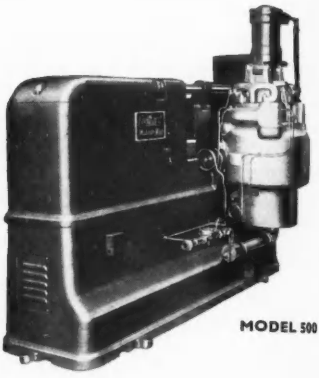

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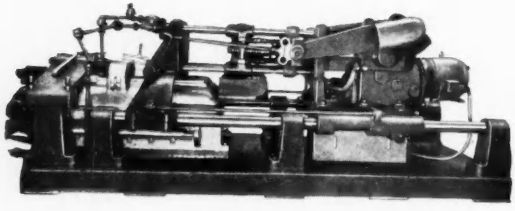

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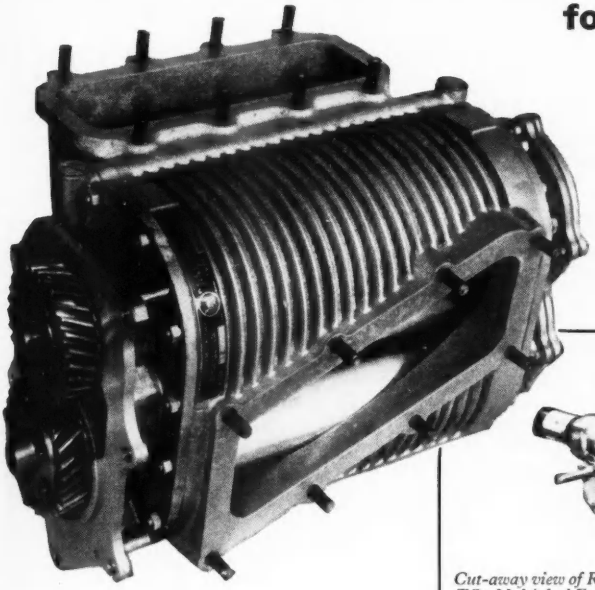
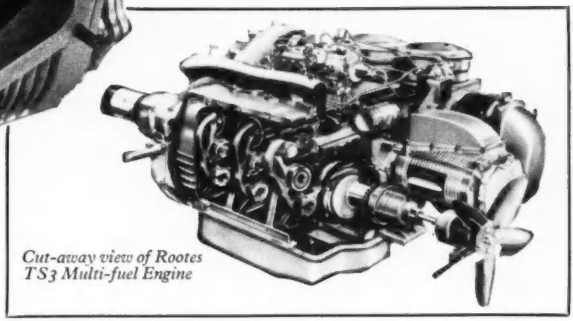


Wade supercharger



Cut-away view of Rootes TS3 Multi-fuel Engine

Superchargers are widely used in oil engines for pressure charging and scavenging and are essential in the opposed piston type. One of the best known designs is the 'Rootes-type' supercharger, made in this country by Wade Engineering Ltd., Brighton.

Quiet operation and maximum overall efficiency are required and a well-designed single helical pair of gears meets these requirements. The driving gear which meshes with a bronze wheel is made from En24V steel and the drive shaft, which has a serrated bore, from En100.

Wade Superchargers are fitted on TS3 opposed piston oil engines made by the Rootes Group to provide versatile and reliable power producers needing little maintenance.

By utilising the better properties obtainable in more highly alloyed nickel steels, dimensions can be reduced, lighter constructions produced, distortion through heat treatment minimised and reliability and economy achieved.

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EN24

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SIZE	HEAT TREATMENT	YIELD STRESS t.s.i.	MAXIMUM STRESS t.s.i.	ELONGATION per cent	IZOD ft. lb.
0.564 in. dia.	Oil quenched 830°C tempered 200°C	111	125	14	24
1⅛ in. dia.	Oil quenched 850°C tempered 510°C	79	83	15	28
1½ in. dia.	Oil quenched 850°C tempered 560°C	68	73	19	55
2½ in. dia.	Oil quenched 840°C tempered 650°C	57	64	20	65
5½ in. dia.	Oil quenched 830°C tempered 650°C	50	58	19	75

Please send for our publications entitled 'The Mechanical Properties of Nickel Alloy Steels' and 'The Case Hardening of Nickel Alloy Steels'

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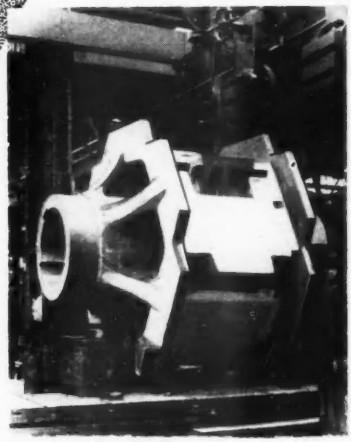
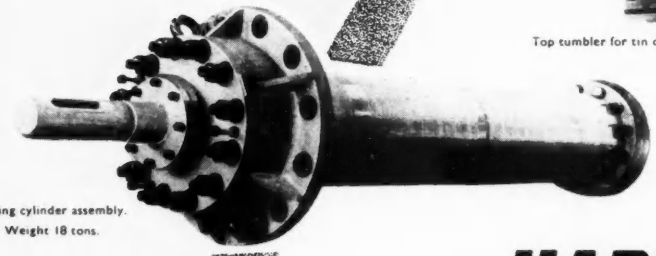


Top tumbler for tin dredging. Weight 17½ tons.



Tilting cylinder assembly. Weight 18 tons.

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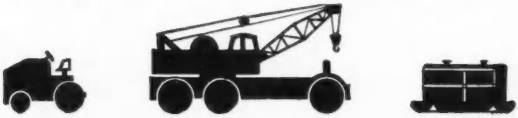

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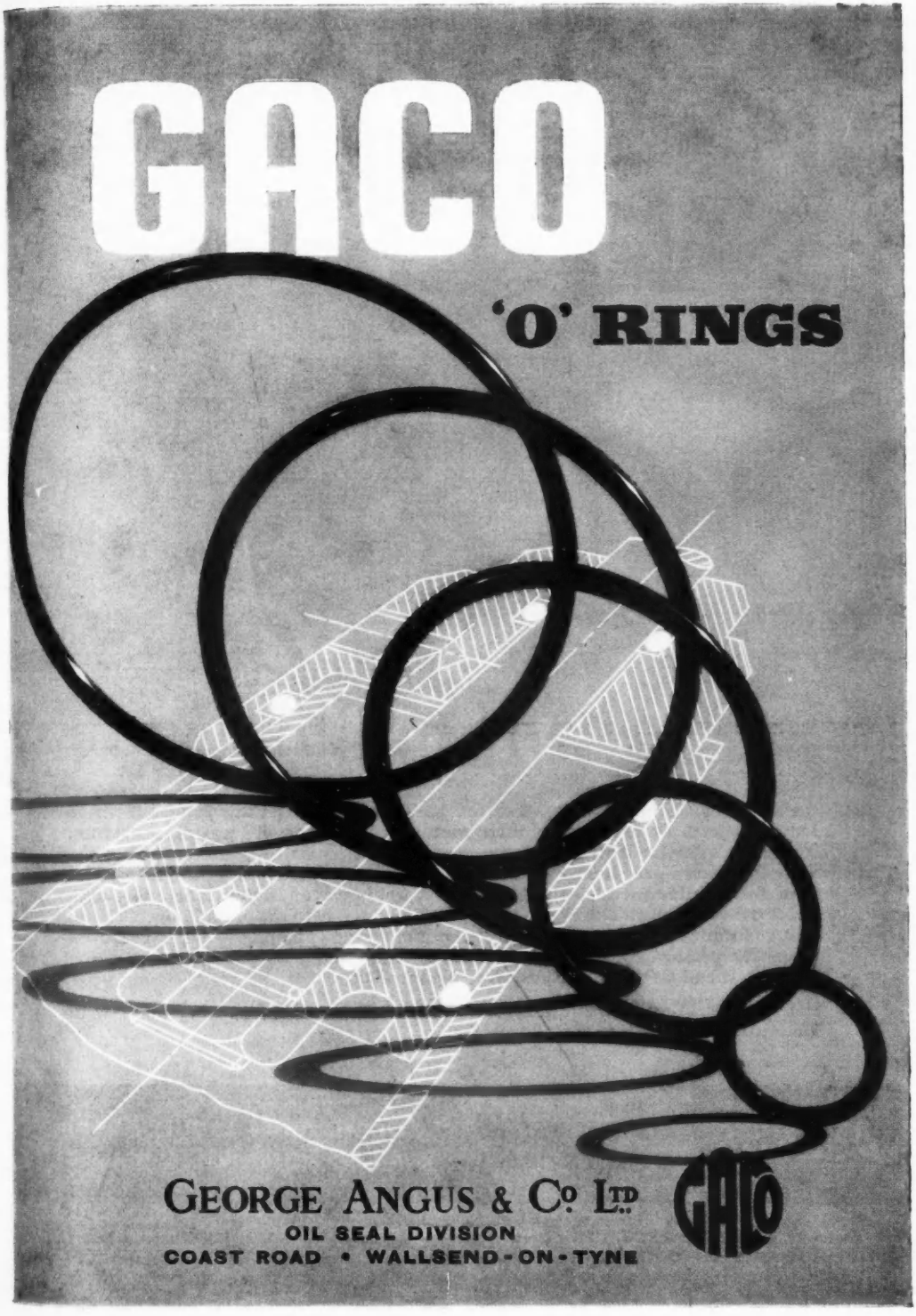
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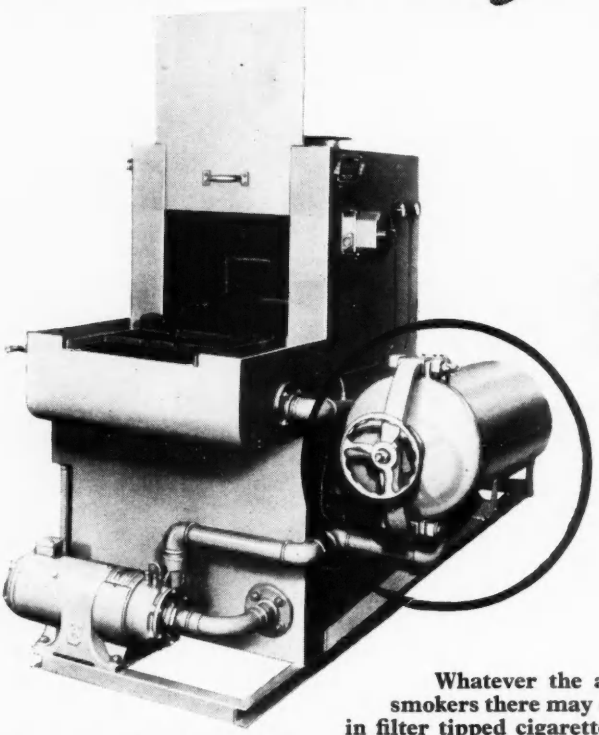

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This fire ventilator saved a plant worth £3,500,000
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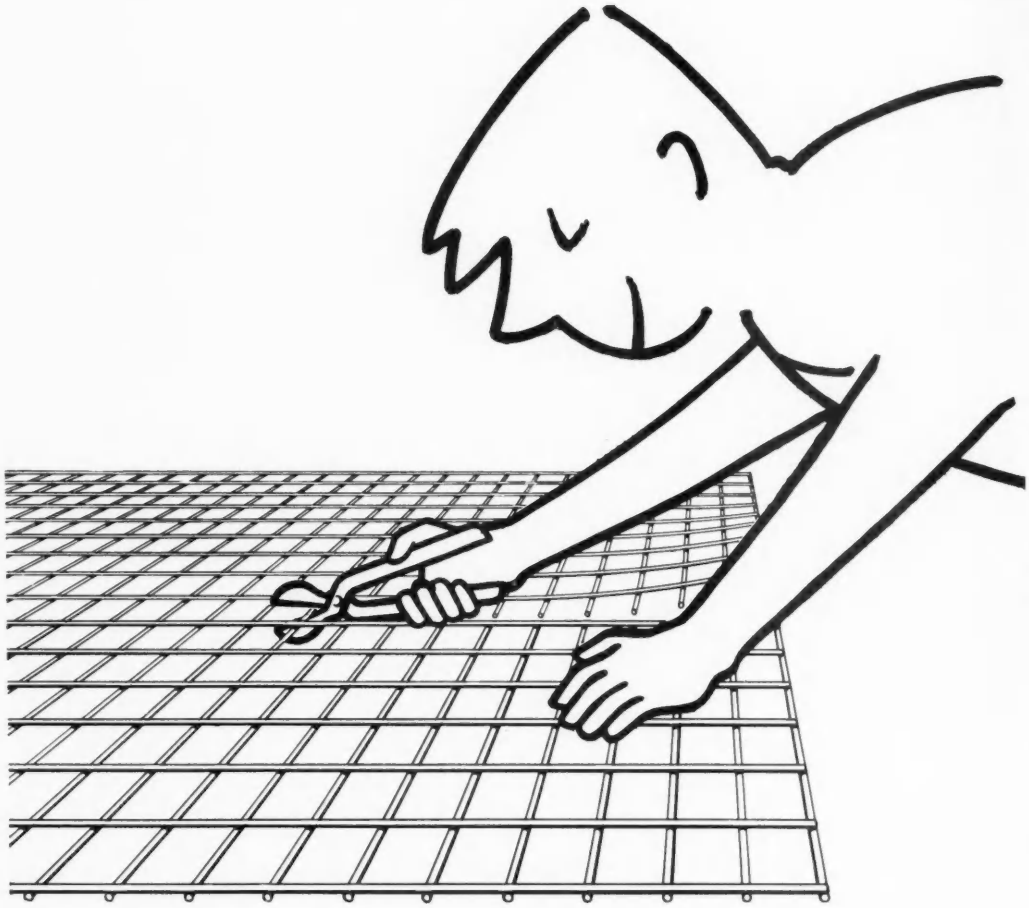

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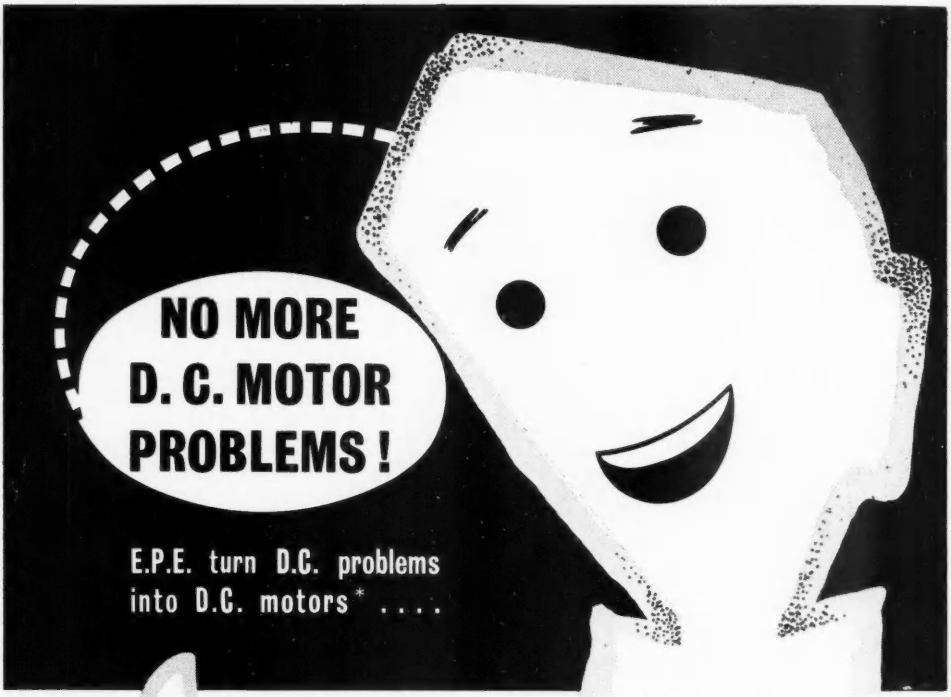

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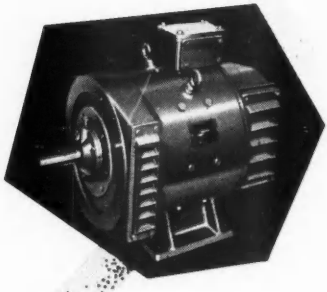

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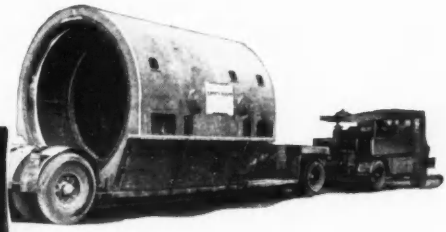

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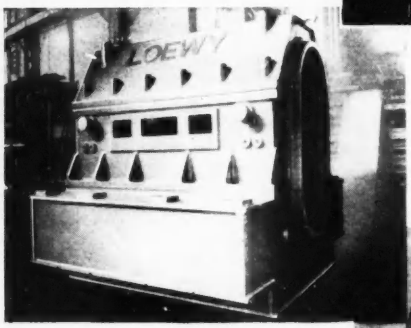

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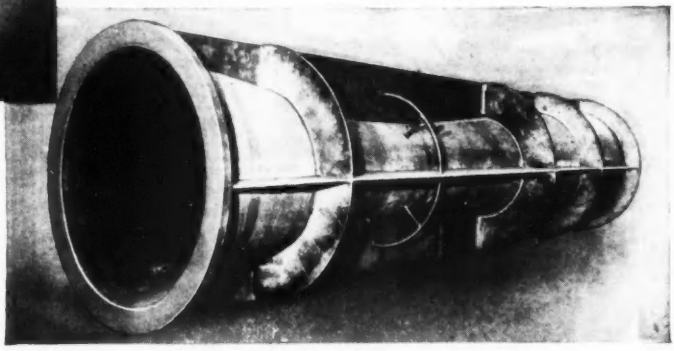

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several plate thicknesses or cable sizes

PAT. APP. No. 5255/59

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Note how when sprung into position the grommet provides a perfect double seal by its own permanent pressures. The angled groove also creates a tight pressure hold on the metal plate.

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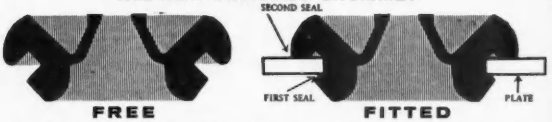

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In the cable grommet variety the same double pressure seal is created, allied to tight seal on various diameters of cable. This new grommet gives sound sealing at *all* vital points.

A useful feature of this cable grommet is that by reason of the designed taper of the cable entry and the flexibility of the web, a considerable angle of cable entry and a variety of cable size are possible. This avoids necessity for special grommets with angled bores.

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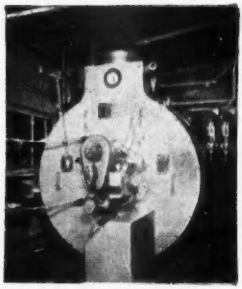

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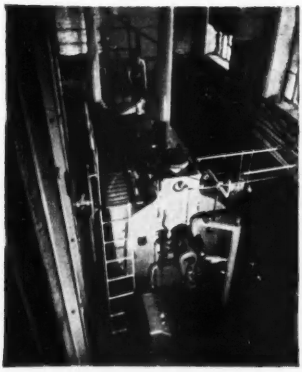

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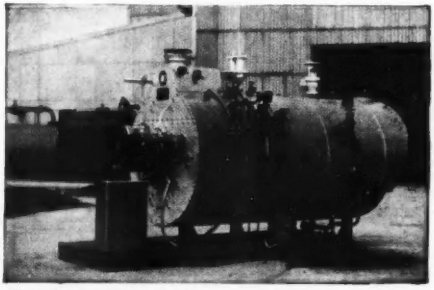

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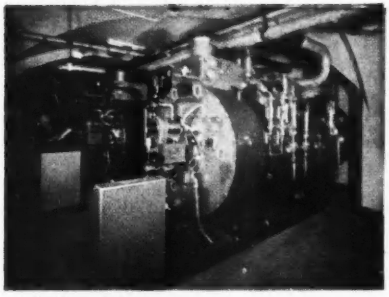

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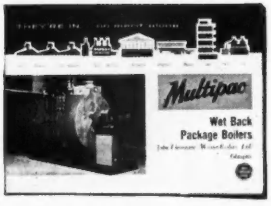

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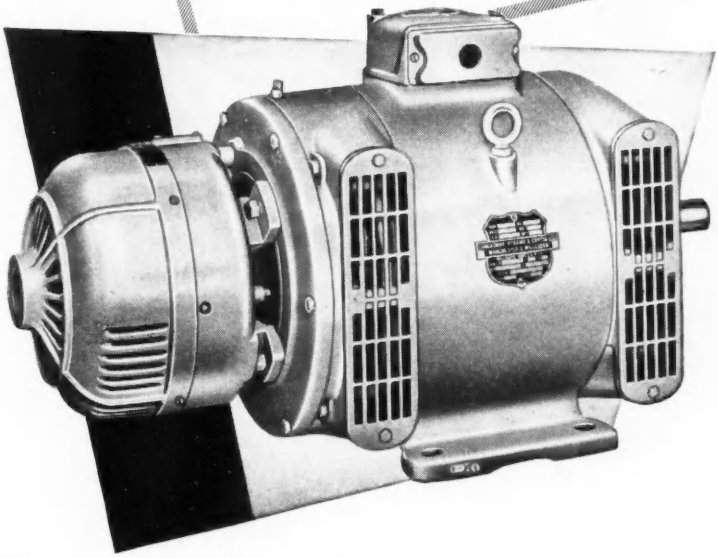

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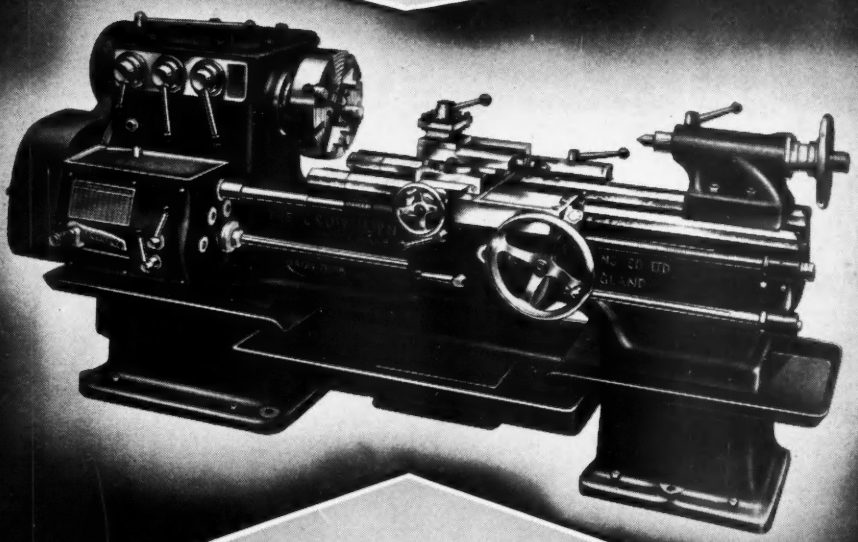

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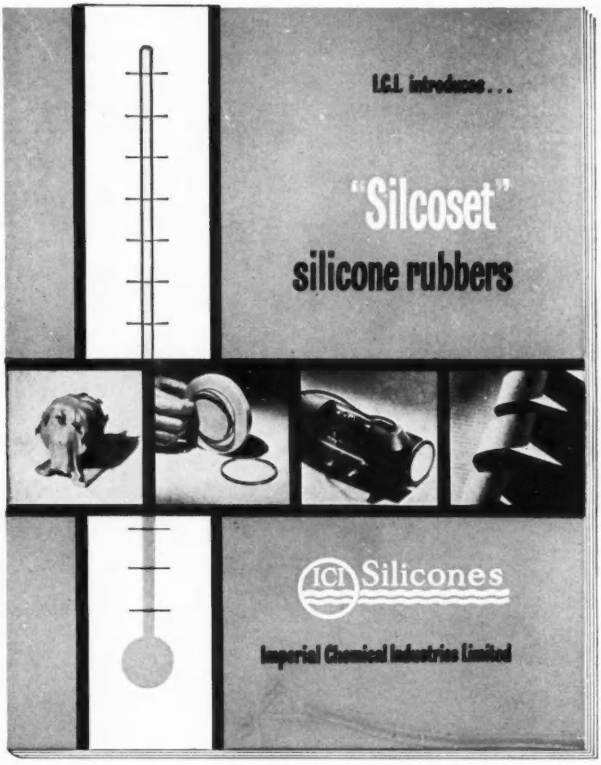

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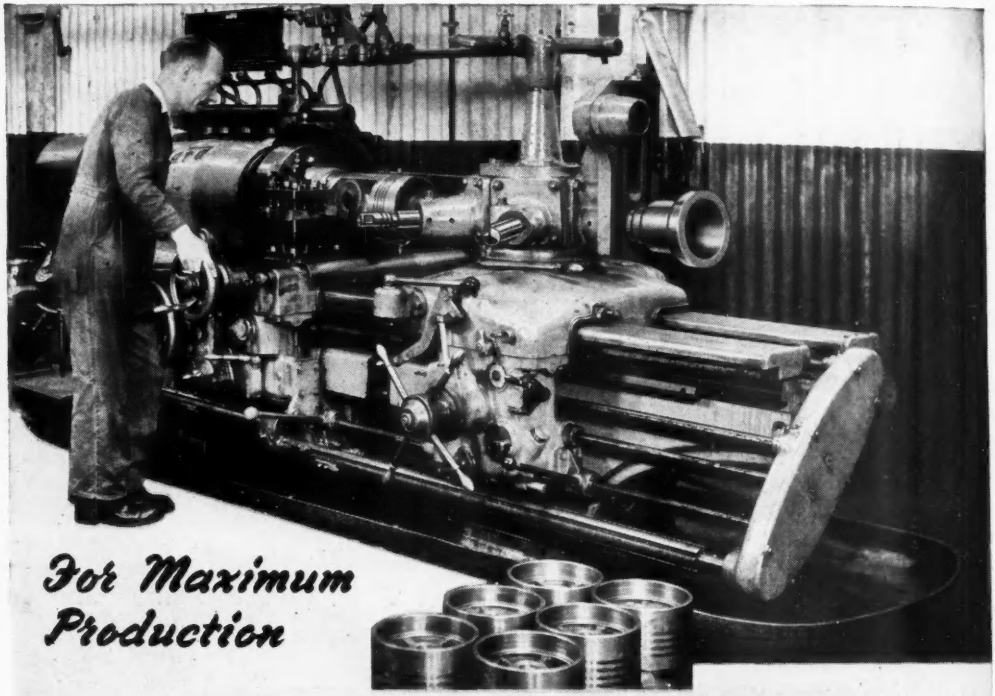

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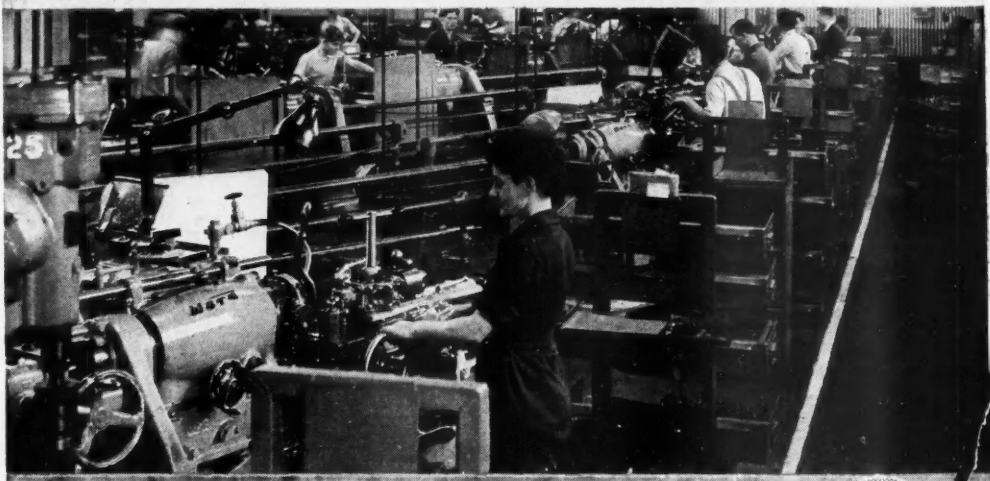

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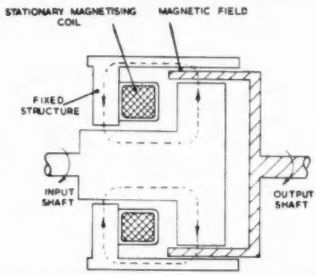

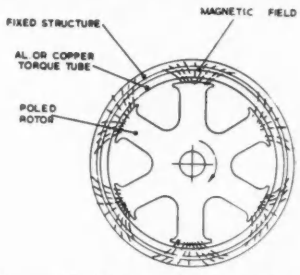

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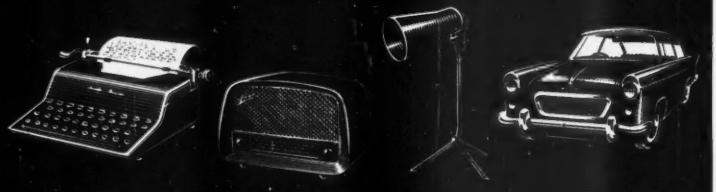

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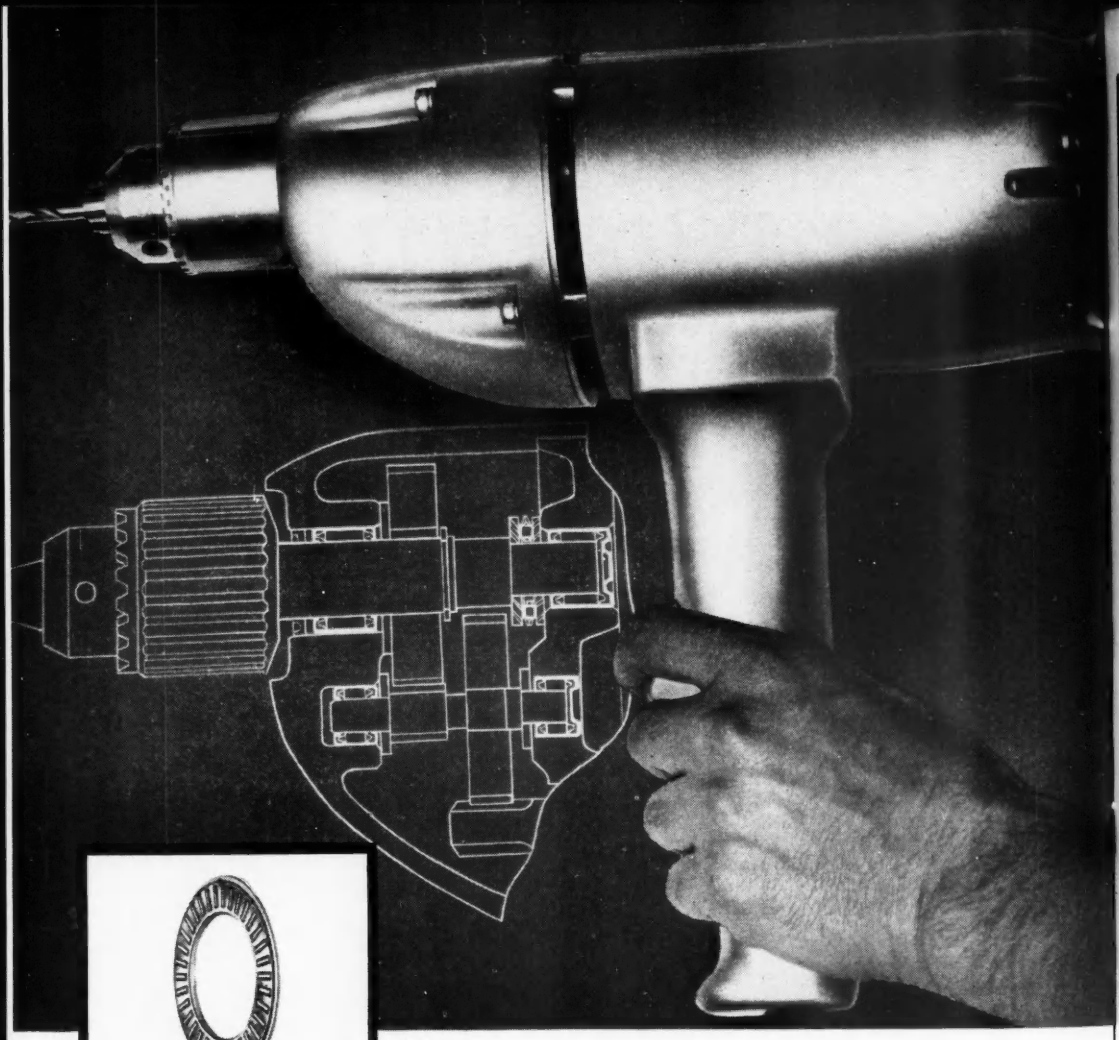

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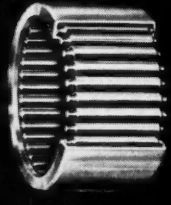
Needle Thrust Bearing



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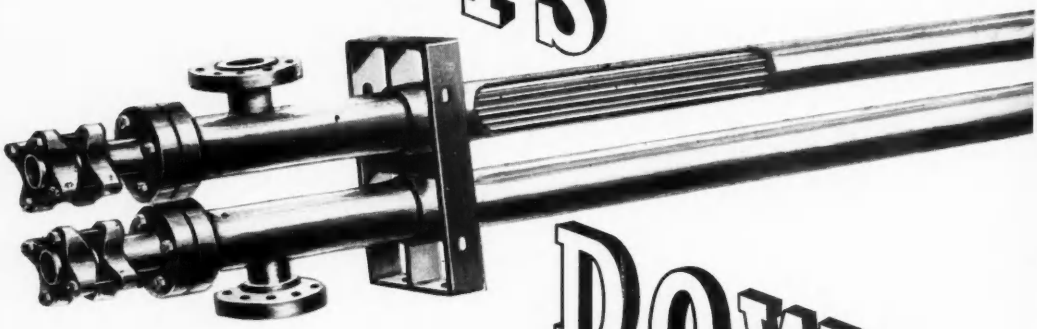

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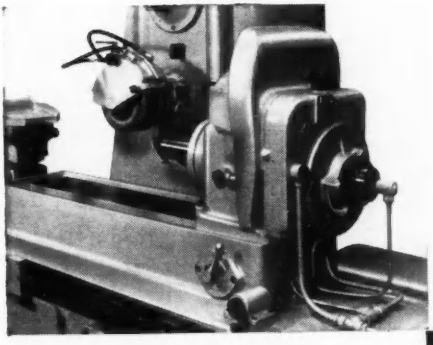

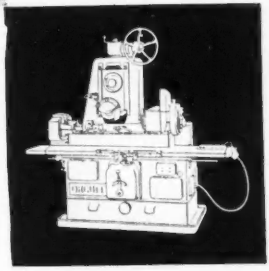

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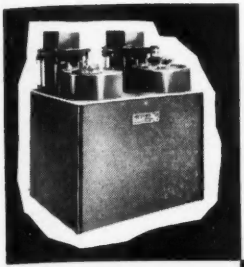
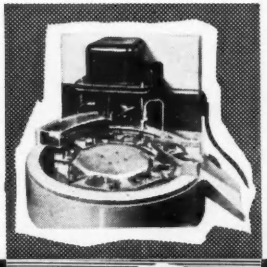
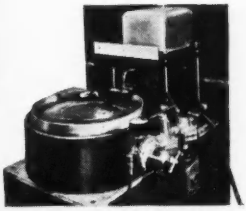
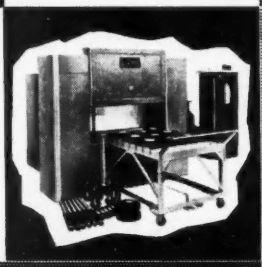


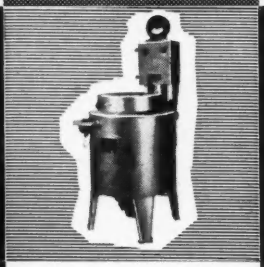
INDUCTION HEATING EQUIPMENT

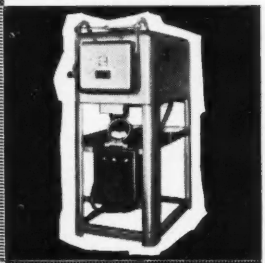


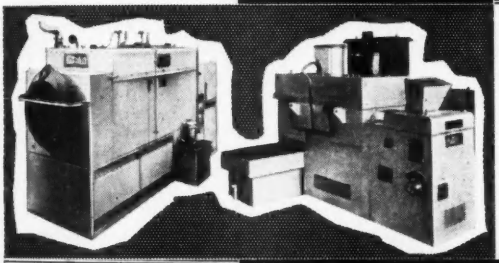


GENERAL PURPOSE FURNACES

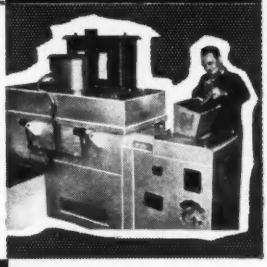


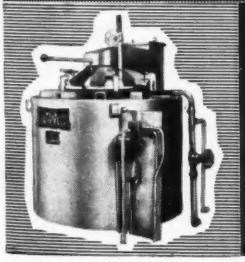


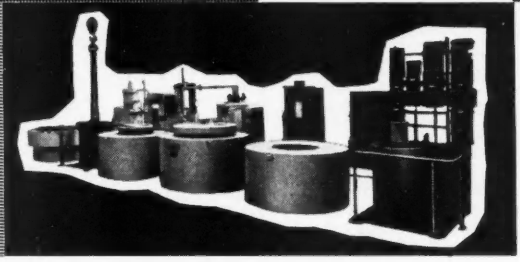




CONTINUOUS CARBO-NITRIDING FURNACES







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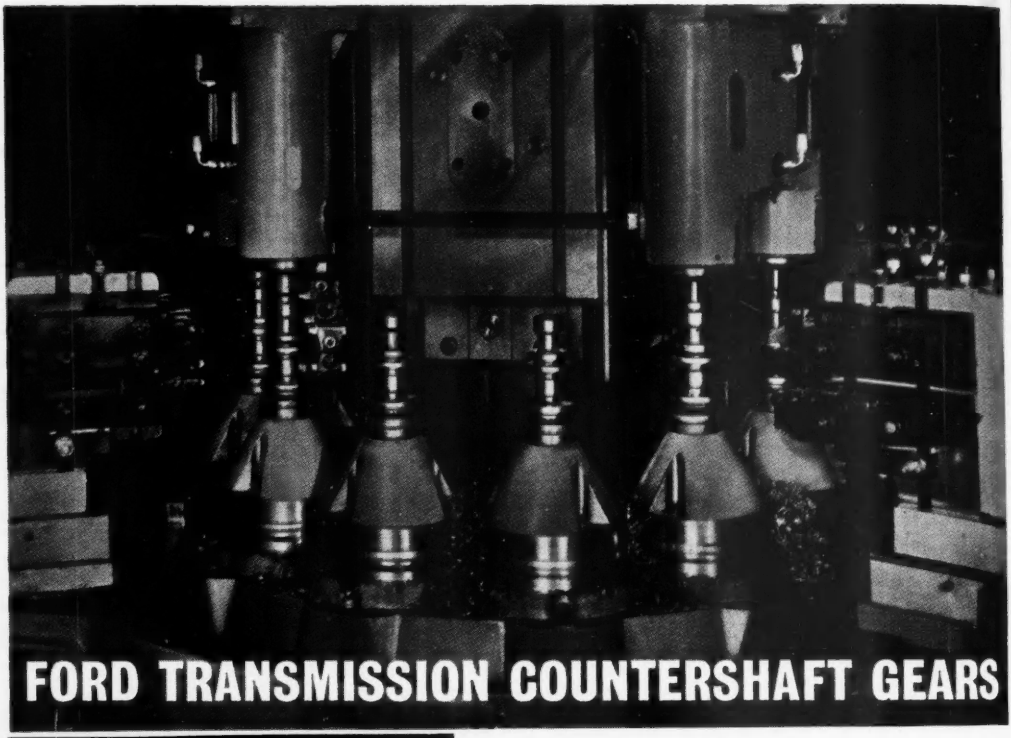
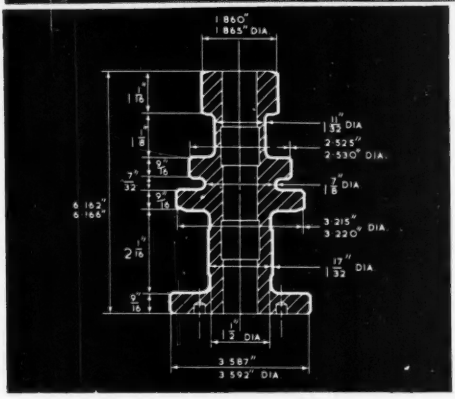


FORD TRANSMISSION COUNTERSHAFT GEARS



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This 12-spindle No. 10 Ryder Verticalauto produces two machined transmission countershaft gears at each index.

Stellite and H.S.S. Tools cutting at moderate speeds and feeds have eliminated swarf problems and hydraulic operation of the mandrels and automatic hydraulic operation of the Loose Headstocks make loading easy to achieve within the cycle time.

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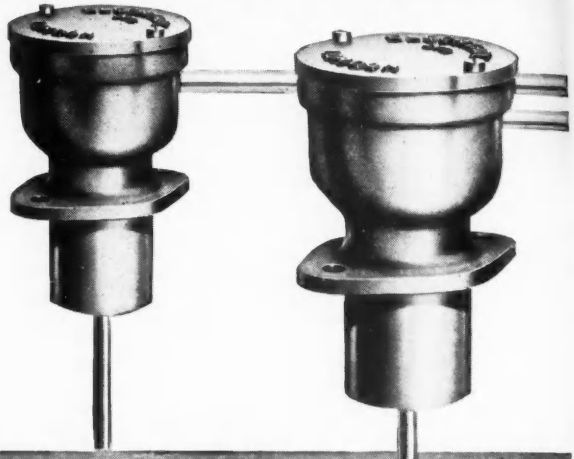

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WHEREVER conductive liquids—and many free-flowing solids—are being handled, the ELCONTROL level control system gives accurate and immediate control of pumps and valves, as well as operating audible and visual signals at desired levels.

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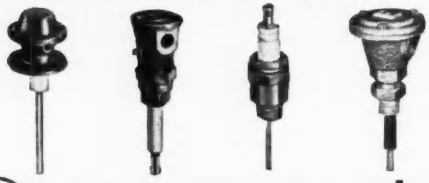
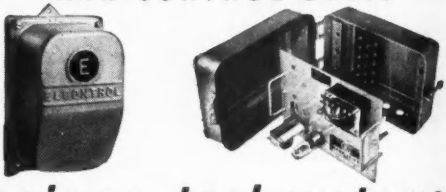


AND CONTROL UNITS



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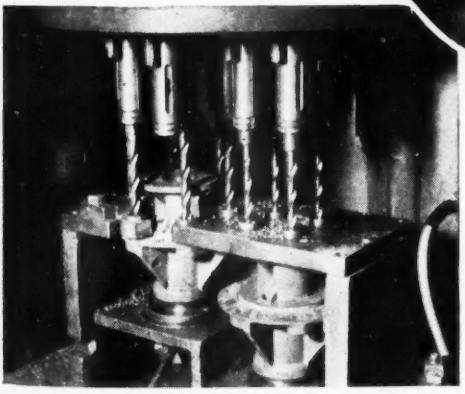

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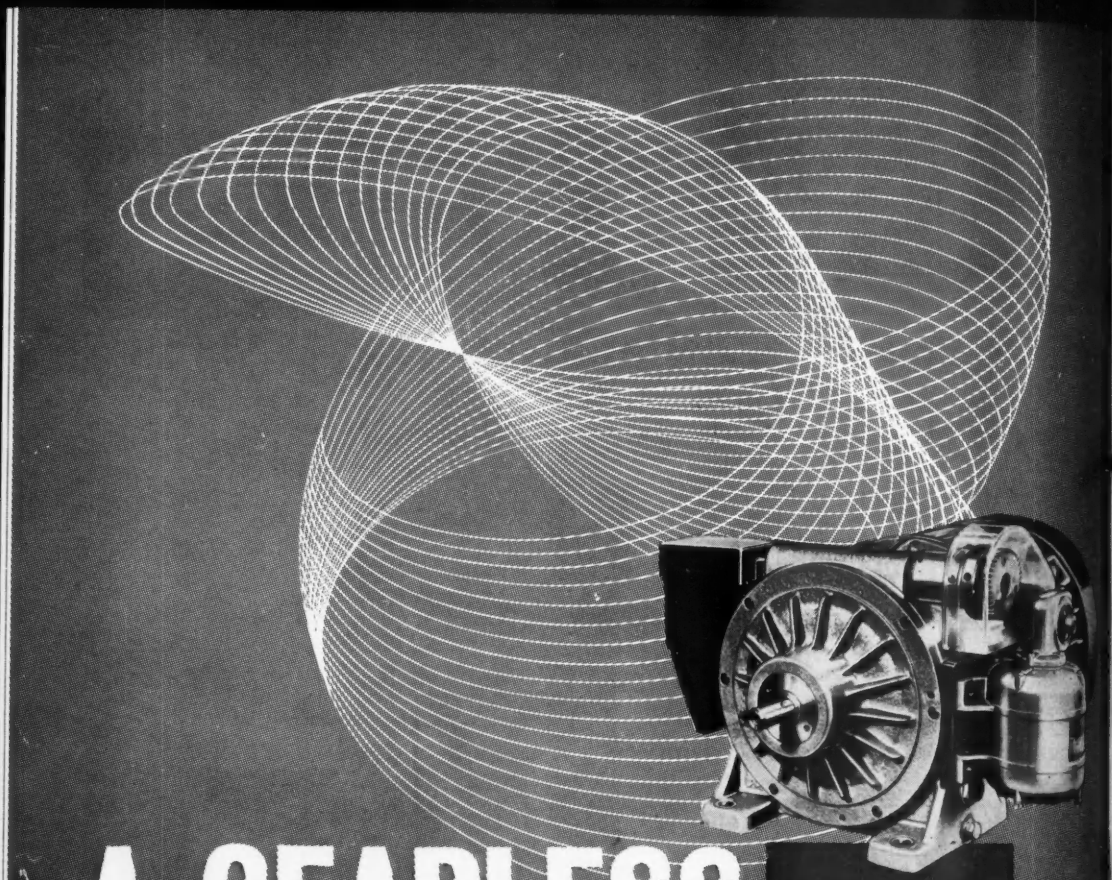

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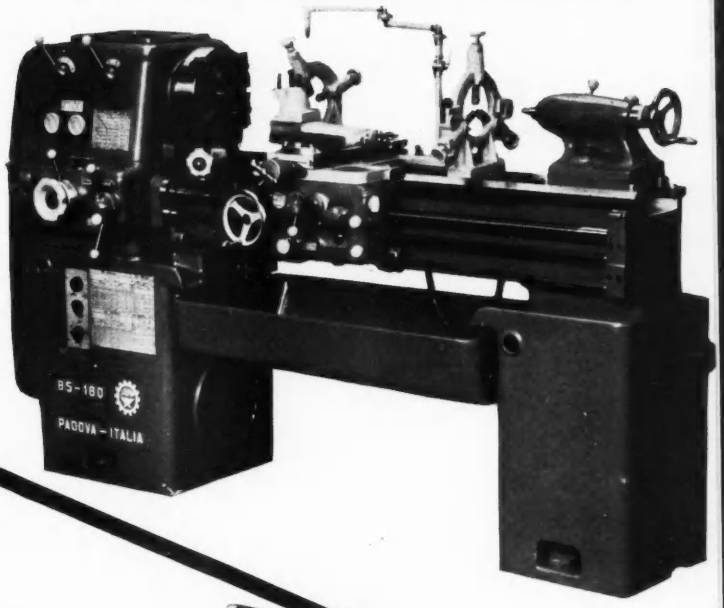
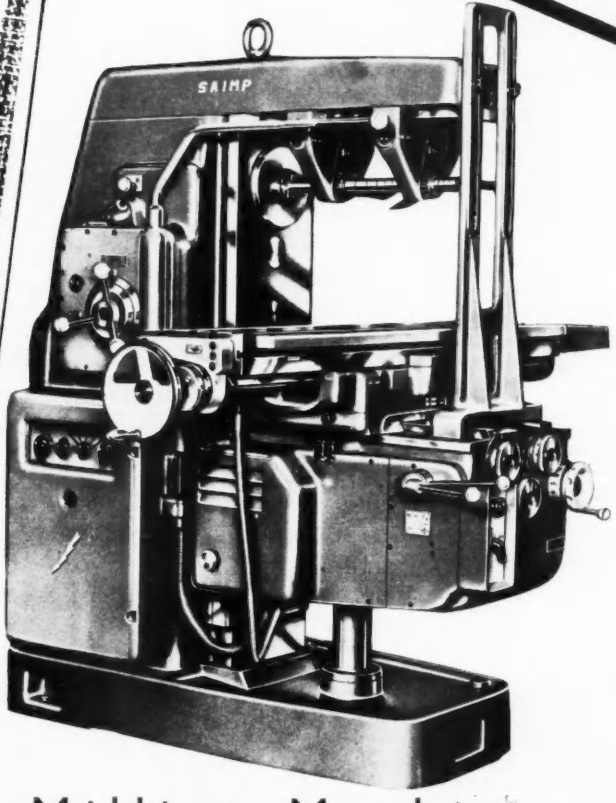


SAIMP 1904



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INTERNAL GRINDER

for production of Injectors
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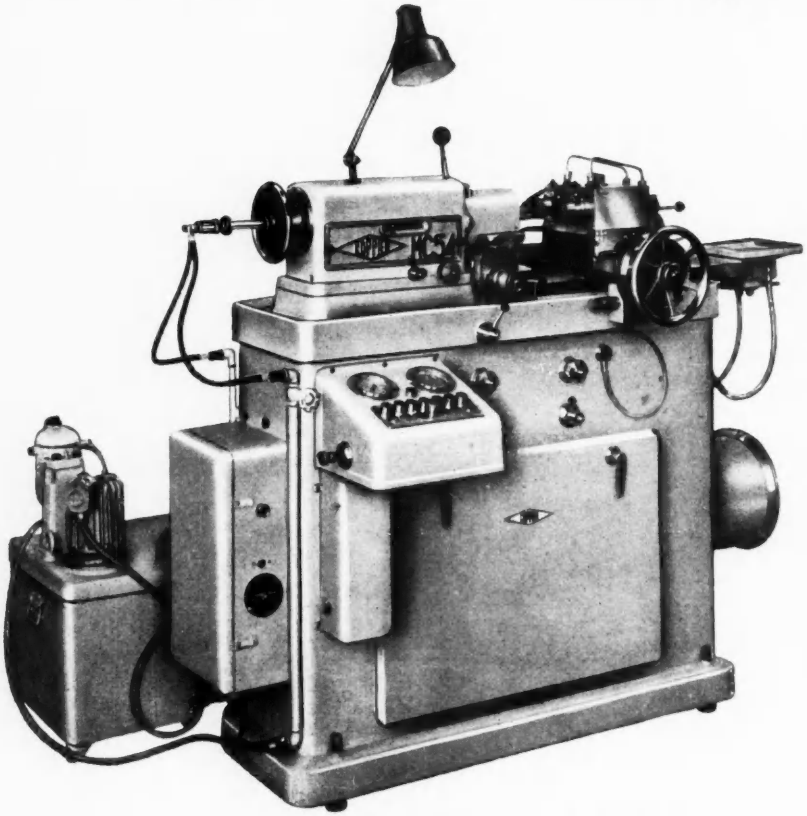

TECHNICAL CHARACTERISTICS

Internal grinder for holes of 1 to 20 mm diameter in high-hardness alloys, e.g., gauges, dies, etc. Spindle speeds from 60,000 to 140,000 rpm.— Quick adjustment for control of diameters, with automatic feed of the spindle head: automatic stop — Supply voltage according to requirements. Weight of complete Grinder approx. 750 kg.

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Grinder specially designed for the mass production of injectors of any type for the internal grinding of gauges and dies in tungsten, carbide and other alloys, for work requiring a very high degree of precision of the order of 0·0003 mm both in roundness and centricity with surface micro-roughness of 0·00025 mm. Perfectly smooth surfaces are obtained, in view of the complete absence of harmful vibrations. The perfect finish of the surfaces, combined with exact geometrical shape, is always assured by the M.C.54 Grinder fitted with patented M.C.52 "Turbo Spindles", with automatic take-up of bearing play, oil-mist lubrication, and other features introduced into its construction. All the adjustments of the individual members of the machine are hydraulically controlled. The machine is fitted with turbine-driven spindles of very high rotational speeds, from a minimum of 60,000 to a maximum of 140,000 rpm; one of these spindles serves to grind cylindrical parts and the other conical parts (e.g. injector and valve seats) according to requirements.

The rotating spindle unit of the M.C.52 "Turbo Spindles" employ a small turbine and the hydraulic system adopted, as compared with electrically-driven spindles, affords numerous advantages, including the following :—

- simplicity of construction.
- variable speed range between the limits required, depending upon the internal dimensions to be ground.
- normal operating speed : 120,000 — 130,000 rpm.
- speed variation between full and no load about 3-4 per cent.
- extremely simple automatic lubrication, without the need for cooling equipment.
- possibility of grinding diameters from 1 to 20 mm.
- automatic take-up of bearing play by means of a patented device which guarantees longer life to the bearings.
- operating life of the spindle at least 800 working hours guaranteed
- high-precision grinding and finishing of the parts.

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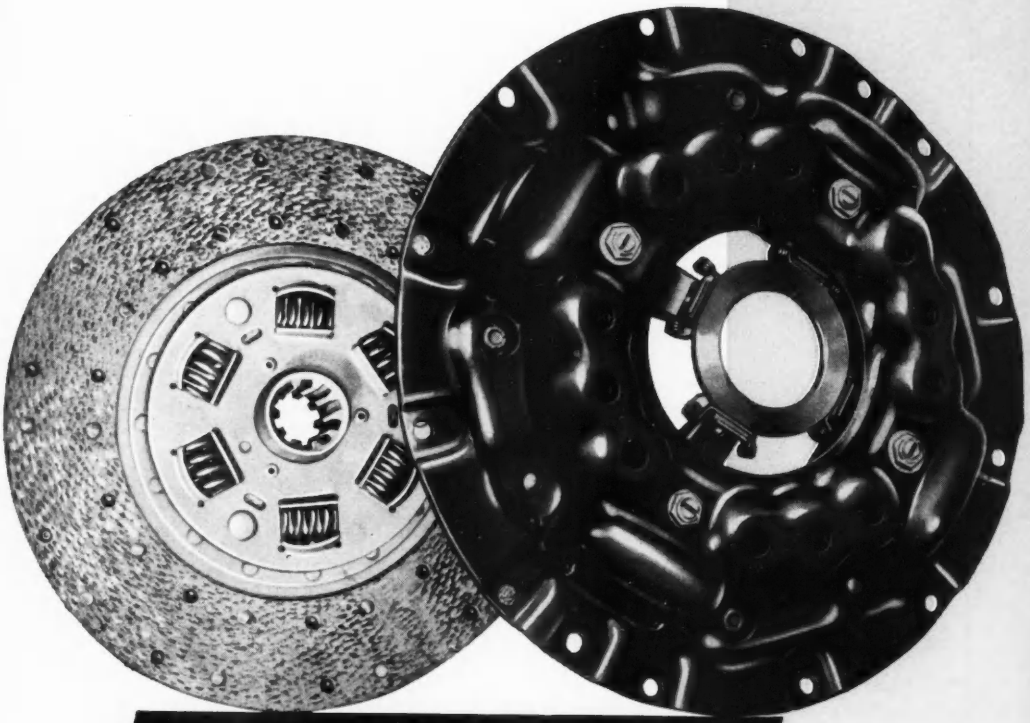

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large and small

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They incorporate the experience gained in the design and manufacture of twelve million British made clutches and embody many distinctive features which ensure consistent and dependable performance.

The top illustration shows the 15-inch single dry-plate clutch, one of a range of 'strap-drive' clutches in which the pressure plate moves without metal-to-metal sliding contact. The smaller unit is a 6¼-inch clutch.

Catalogue of Borg & Beck clutches and Rockford over-centre clutches and power take-offs on application.

BORG & BECK

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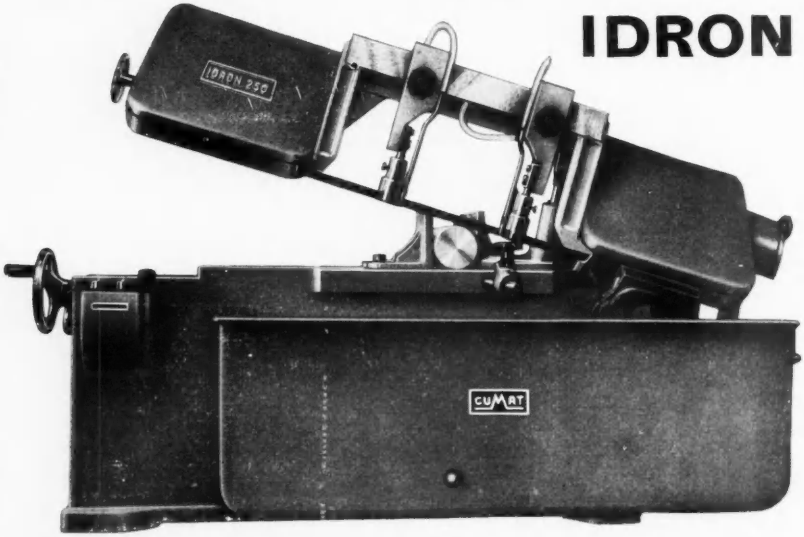
HORIZONTAL HIGH-SPEED BANDSAW

IDRON 250



- Maximum cutting capacity
  round stock 250 mm.
  rectangular stock 200 × 400 mm.
- Work holder swivels to 45°
- 4 cutting speeds

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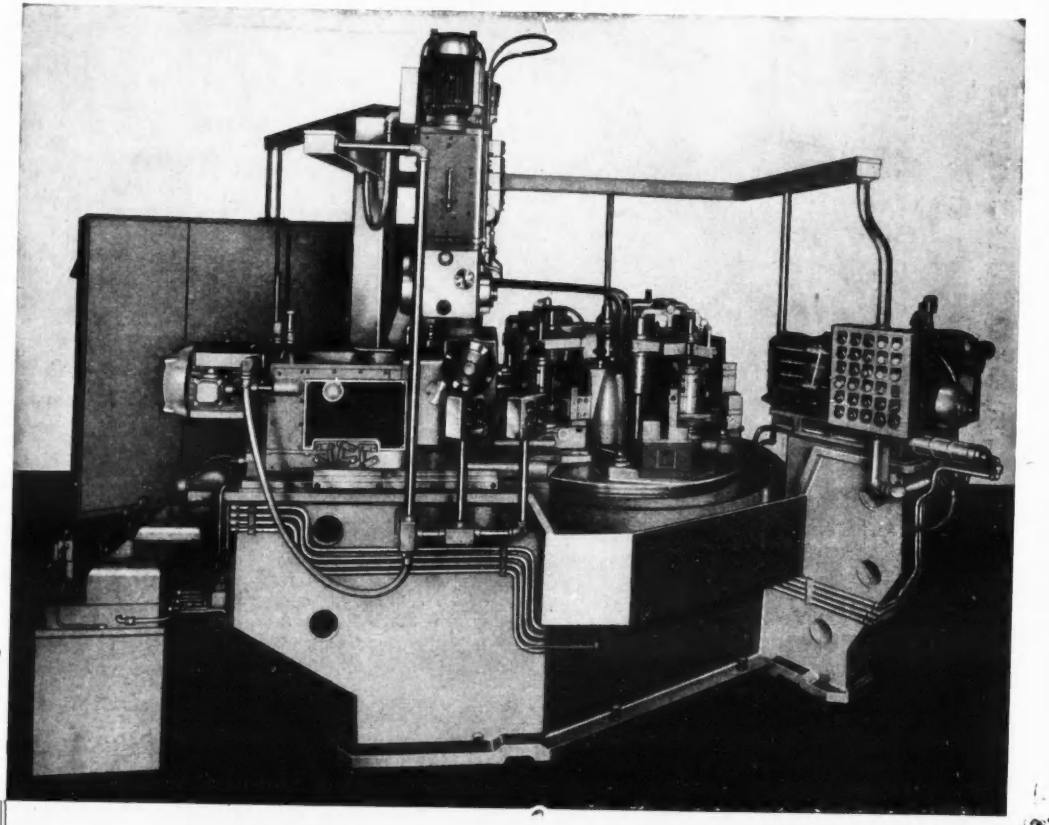

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L. 46/52	„	„	52 mm.
L. 52/64	„	„	64 mm.

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Model L. 30, L. 36/42 and 46/52 are electro-magnetically controlled.

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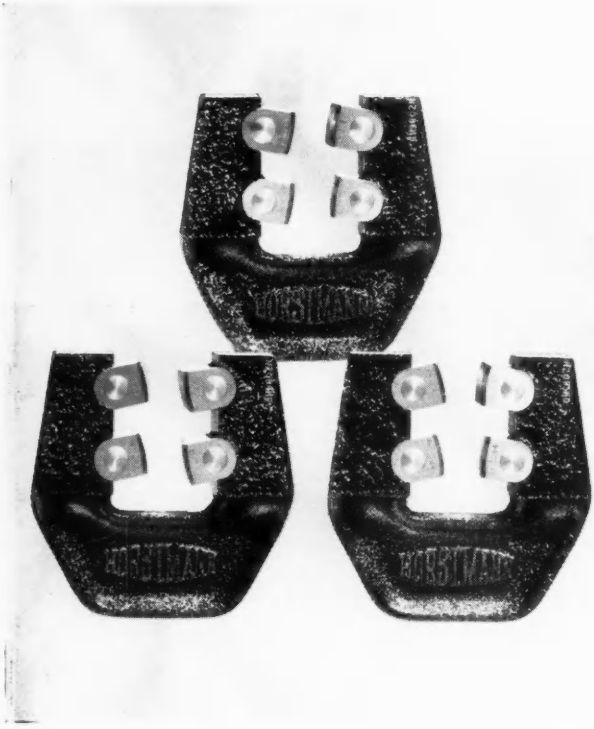
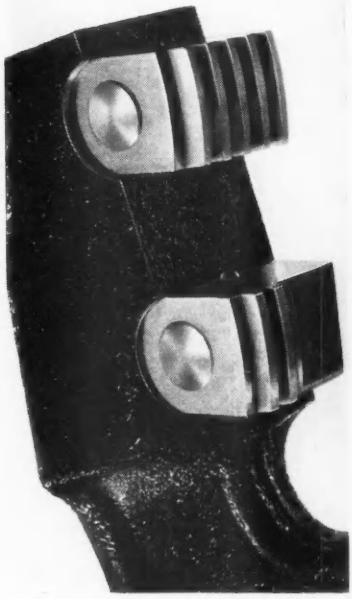
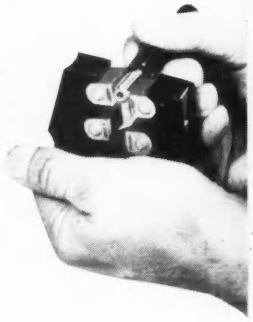




Horstmann—A gauge of accuracy

And—for good measure—the Horstmann Model 52 Screw Caliper Gauge incorporates several features which make it versatile, easy to handle and long-lasting.

One of its advantages (as can be seen from the illustrations) is that there are no projections from the side of the Caliper frame; therefore shouldered work can easily be gauged. Adjusting screws allow for a wide range of work diameters and tolerances, and are used for readjusting to size when the gauges becomes worn. The depth of the anvil section prevents shearing and makes the Horstmann Model 52 ideal for gauging Acme forms of thread. The radiused anvils do not roll and can be used for either left- or right-hand threaded workpieces. The Caliper is normally supplied as a "GO" and "NOT GO" combination gauge so that both tests can be applied in one action, but is also available as "GO" only or "NOT GO" only. It is manufactured in a full range of B.A., American, Unified, Whitworth, and Metric forms of thread.



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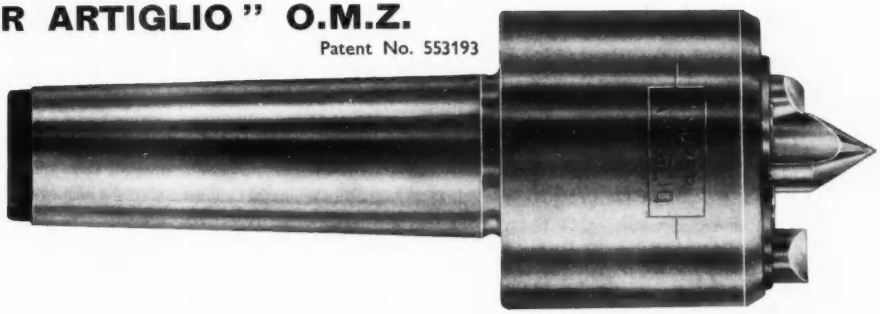
FACE DRIVER "SUPER ARTIGLIO" O.M.Z.

Patent No. 553193



Indispensable for turning, milling, and gear cutting. Replaces expensive or obsolete equipment. The workpiece can be unclamped while the machine is running, and can be perfectly centred with a single chucking operation as the driver centre rotates with 1/100 tolerance.

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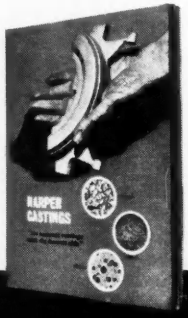

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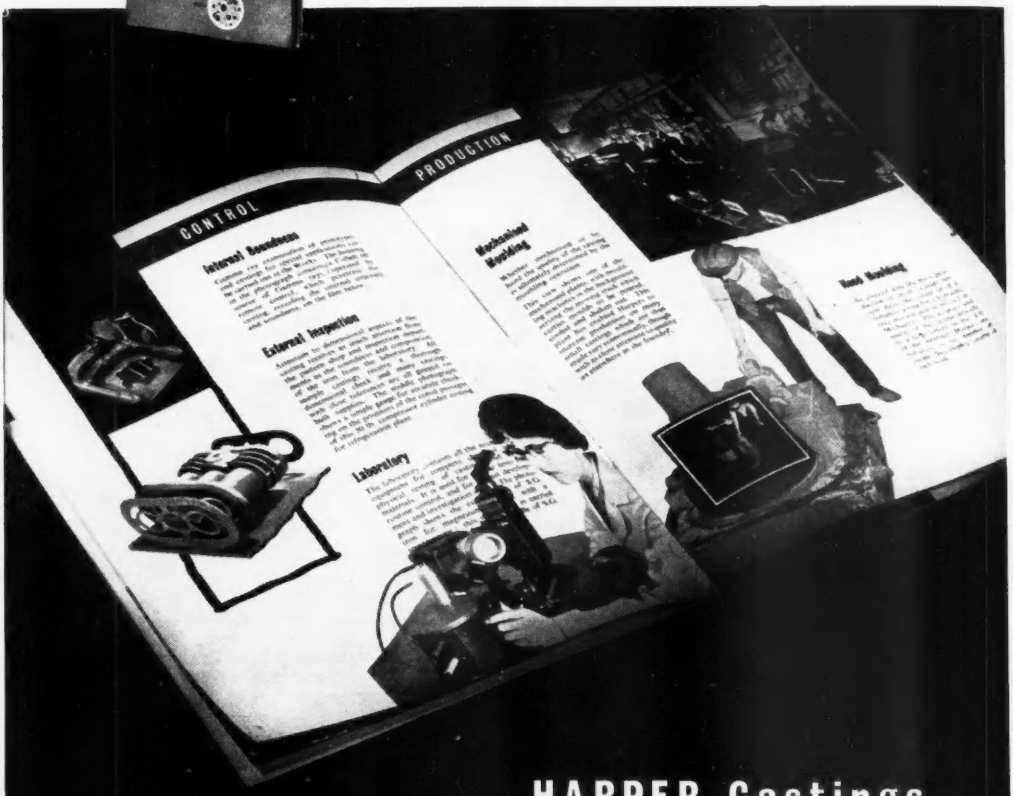

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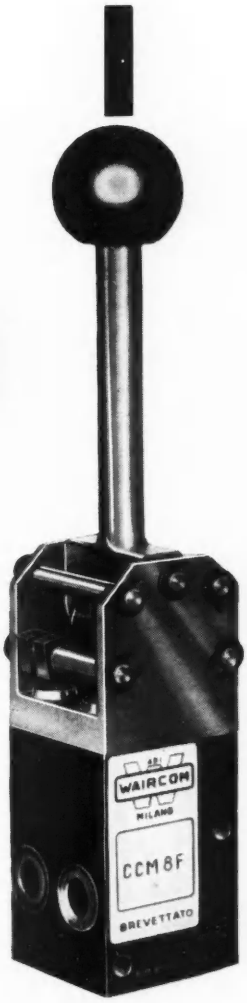

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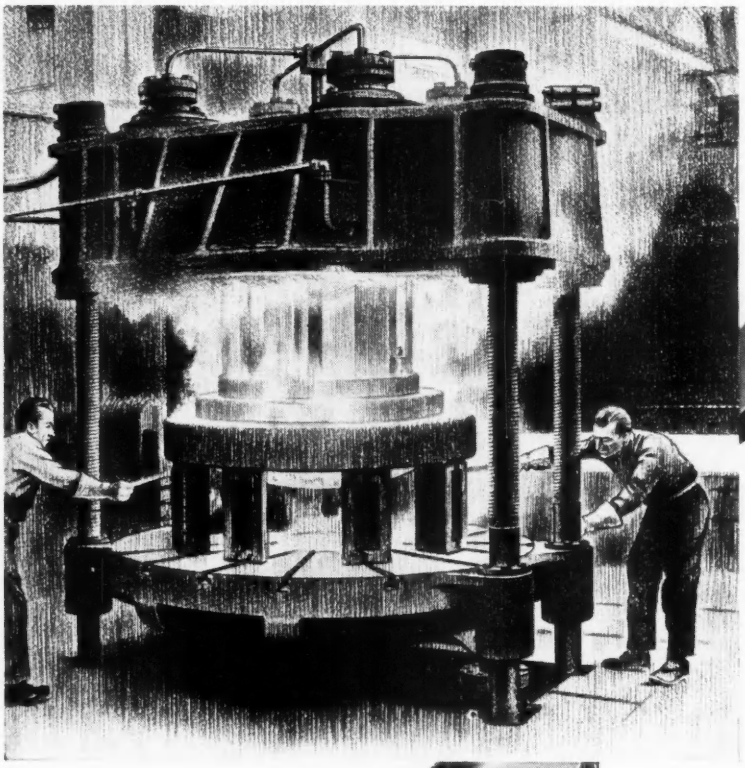

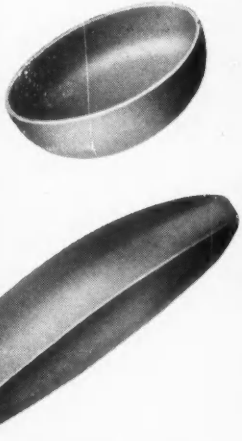

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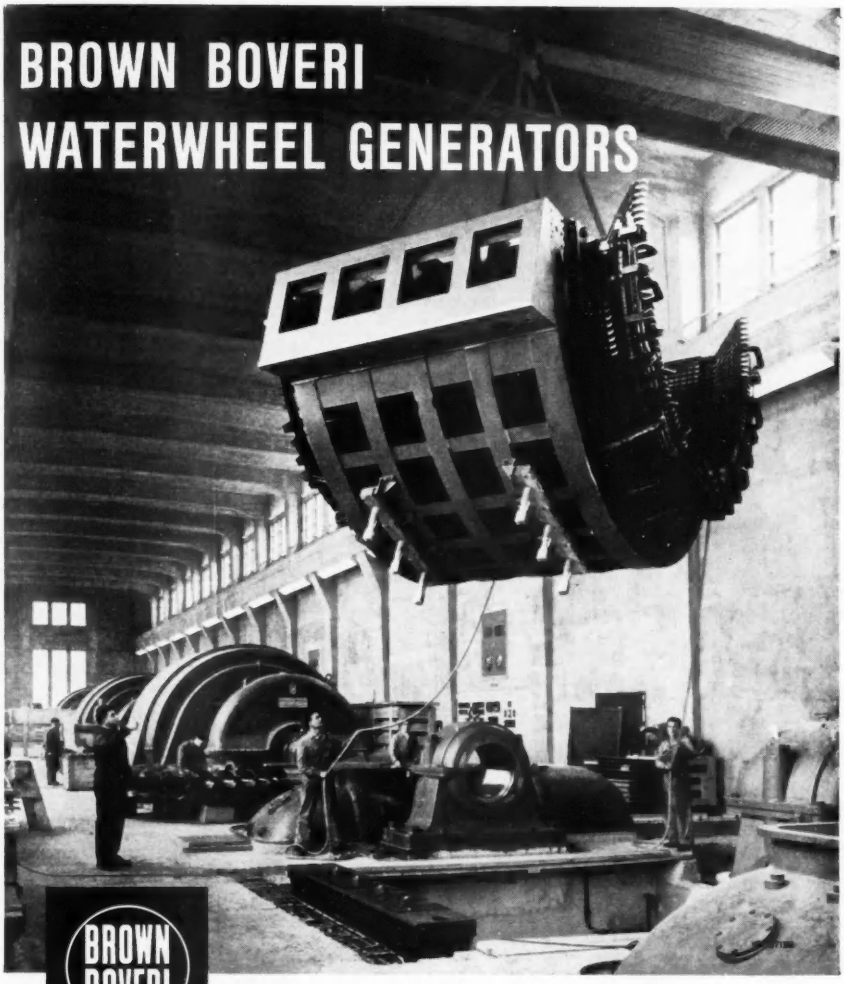

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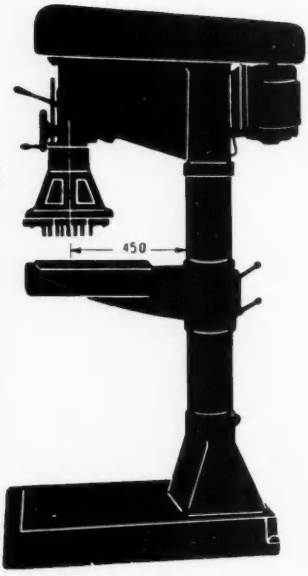

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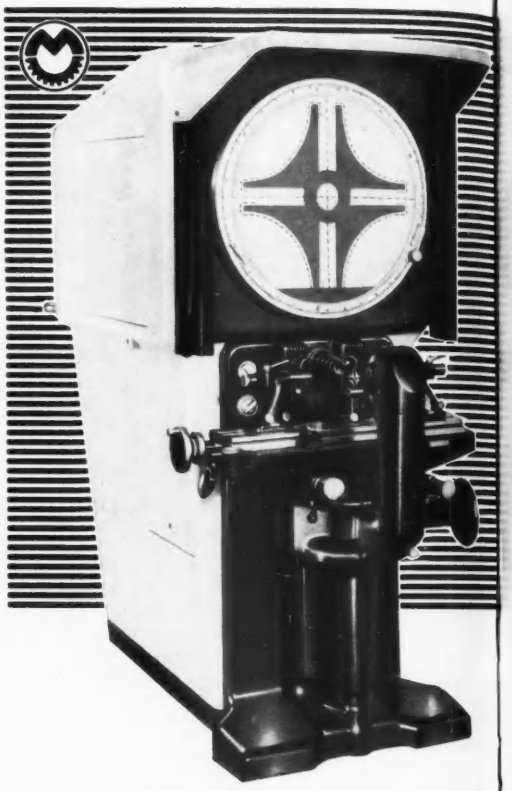

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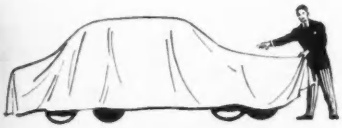

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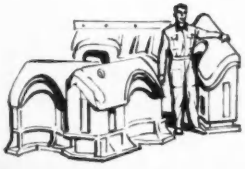

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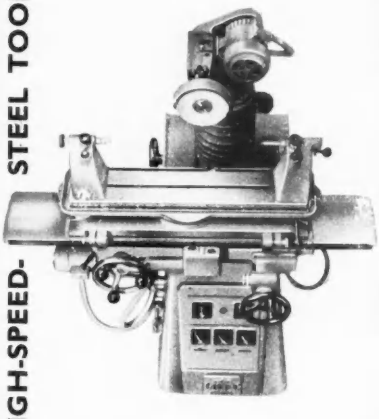

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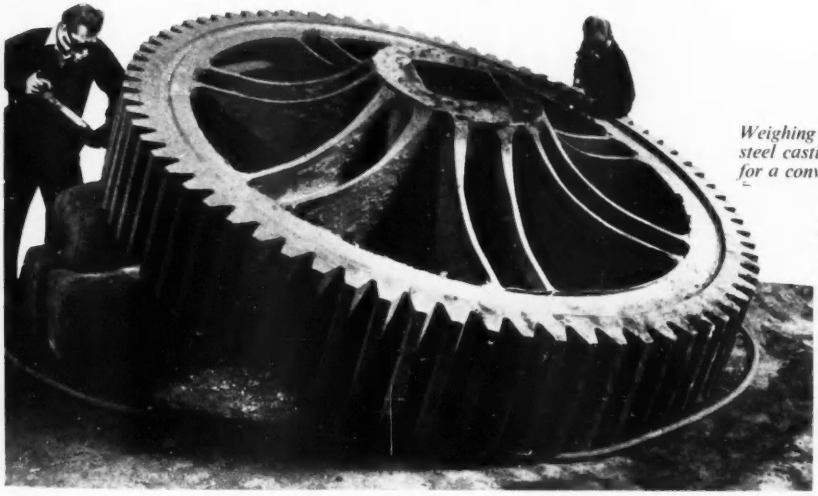

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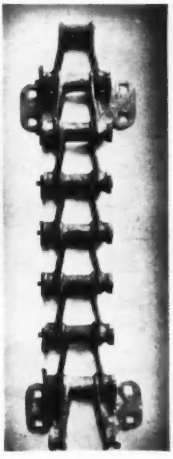

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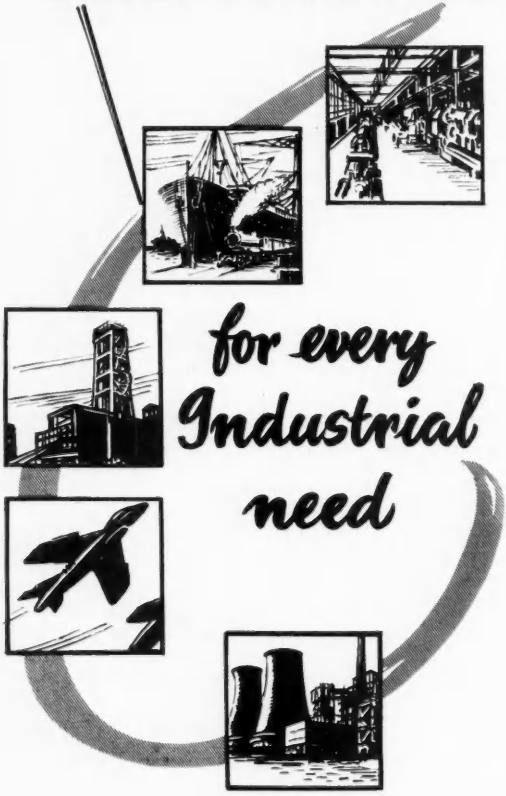

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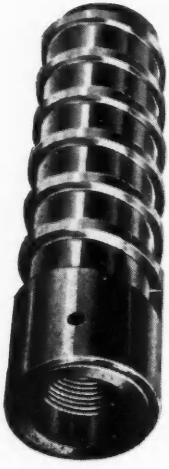

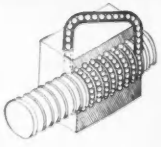

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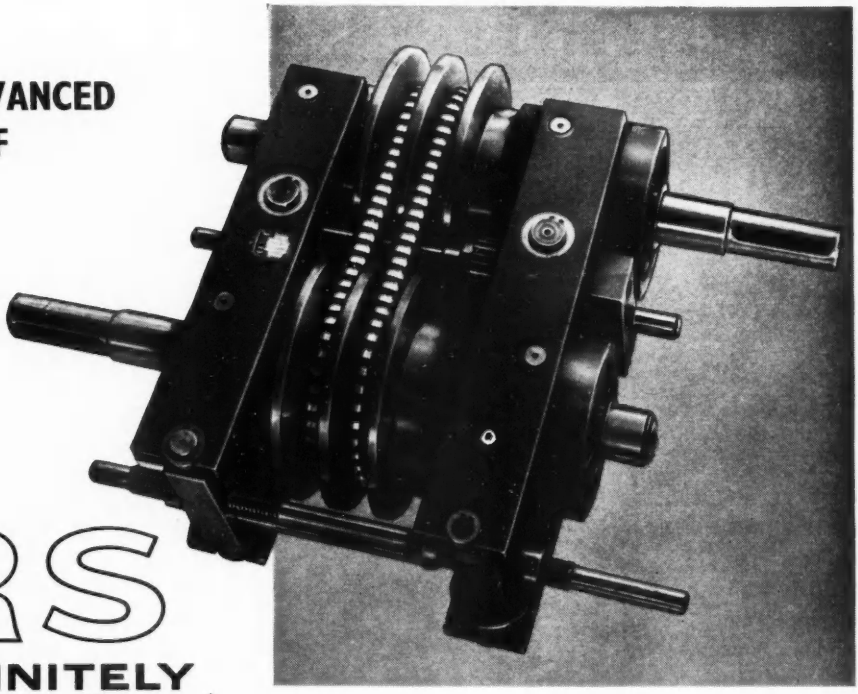

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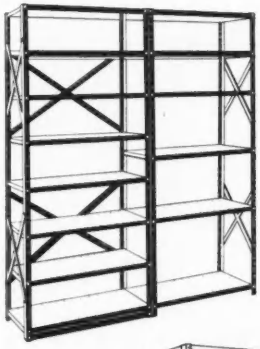

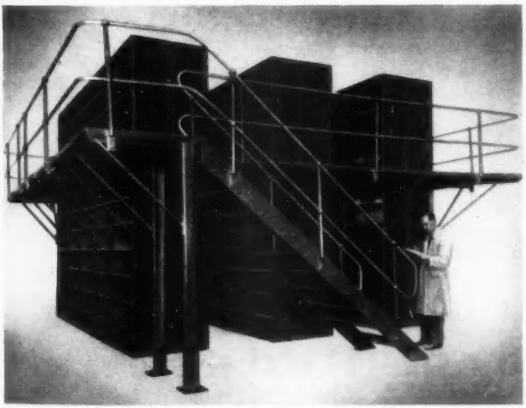

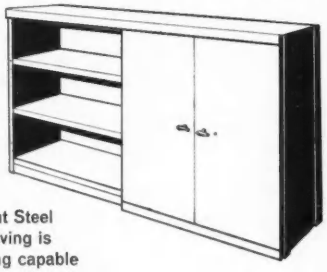

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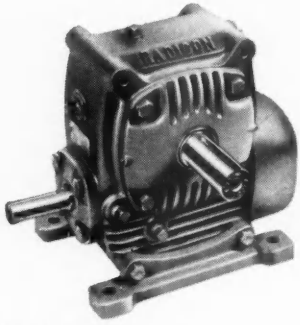

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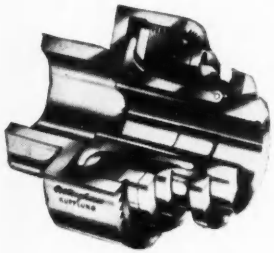
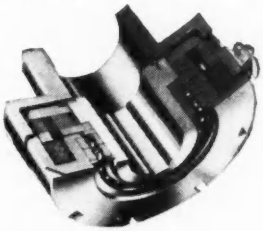
Ortlinghaus

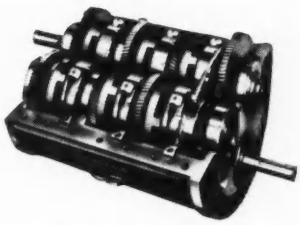
– a complete service in the field of power transmission



Mechanical multi-disc clutches and brakes.

Maintenance-free, slipring-less electro-magnetic "Sinus" multi-disc clutches.





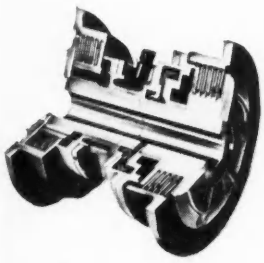
Automatic power shift gearbox.

Pioneers of the Multi-Disc Clutch and originators of the famous "Sinus" Sprung Steel Laminations, ORTLINGHAUS have held a leading position in the world Clutch Market for more than fifty years.

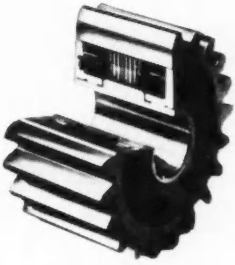
"Sinus" Multi-Disc Clutches have proved their superiority and complete dependability in literally millions of cases, and are available as mechanically, pneumatically, hydraulically or electro-magnetically operated models. The complete answer to push-button and automatic transmission problems, is the ORTLINGHAUS Type 25 Electro-Magnetic Clutch which is slipring-less and requires no maintenance whatever. This type of Clutch is used in the highly successful ORTLINGHAUS Automatic Power-Shift Unit—one of a range of standardised gearboxes for many purposes.

The vast range of ORTLINGHAUS Products, together with their wide experience, is now available from the Clutch Division of Soag Machine Tools, whose Specialists are at your disposal to advise on all problems arising from the design and manufacture of power transmissions.

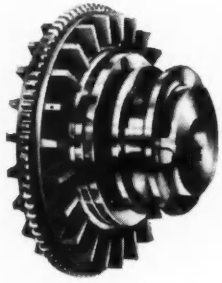
Comprehensive clutch and geared drive catalogues availableon request.



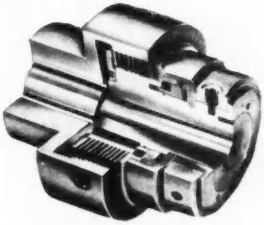
Pneumatic multi-disc clutches and brakes.



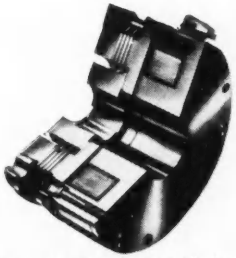
Adjustable slipping clutches.



Mechcnical turbo-cooled single and twin dry plate clutches.



Hydraulic self-cdjusting multi-disc clutches and brakes.



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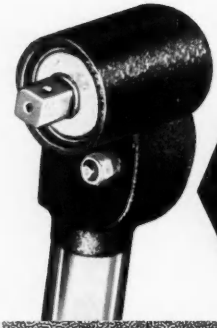

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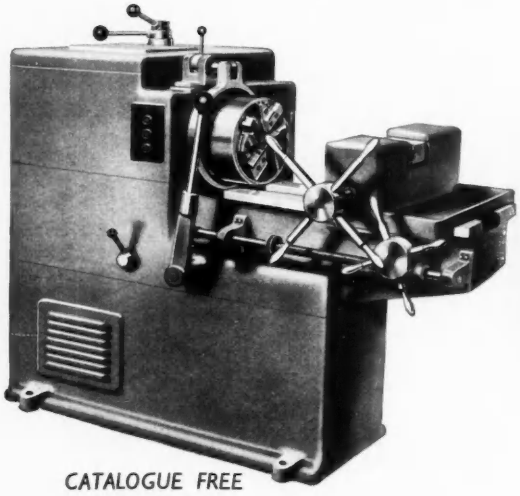

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These machines have been especially designed for quantity production work, and they are capable of extremely fast rates of output. Outstanding features include Tangential Die Head, Hand and Automatic Releasing Motion, Automatic Closing Device, Automatic Pump, etc.

A full range of sizes is available

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There's talk of Sykes at the airport . . .

A leading aircraft engine manufacturer wanted machines and cutters to generate internal gears and splines on compressor centre shafts for jet engines. The components were hollow, high tensile steel tubes from 3″ to $7\frac{1}{4}$″ diameter in a number of lengths up to 3ft. Moreover, in places the wall thickness was less than $\frac{1}{8}$″, and the limit of eccentricity between gear pitch line and the tube diameter was .0005″ maximum.

He went out for the best advice because the problem was a difficult one—unusual component length, plus the need to maintain the highest precision in a part which could distort very easily.

Sykes Technical Advisory Service introduced him to Sykes horizontal gear generators, highly versatile machines for the production of internal spur and helical gears and splines.

Today, a Sykes horizontal gear generator—with a modified internal cutting attachment and special work-holding equipment—is producing the whole range of required components to limits well within those specified in the original enquiry drawings. And the machine can always be quickly adapted for conventional work.

Talk to SYKES about gear production

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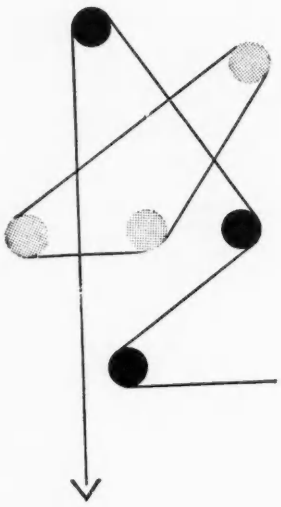
Sykes Machine & Gear Corporation, Newark, NJ, USA
W. E. Sykes Ltd. Mascot, Sydney, NSW, Australia



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- ★ **Elasticity**

Stephens Belt Drive Computer FREE to Engineers and Designers, asking for it on business note headings.

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This A & A process is also a heat insulator and will absorb and retain oil when used on cylinders and pistons.

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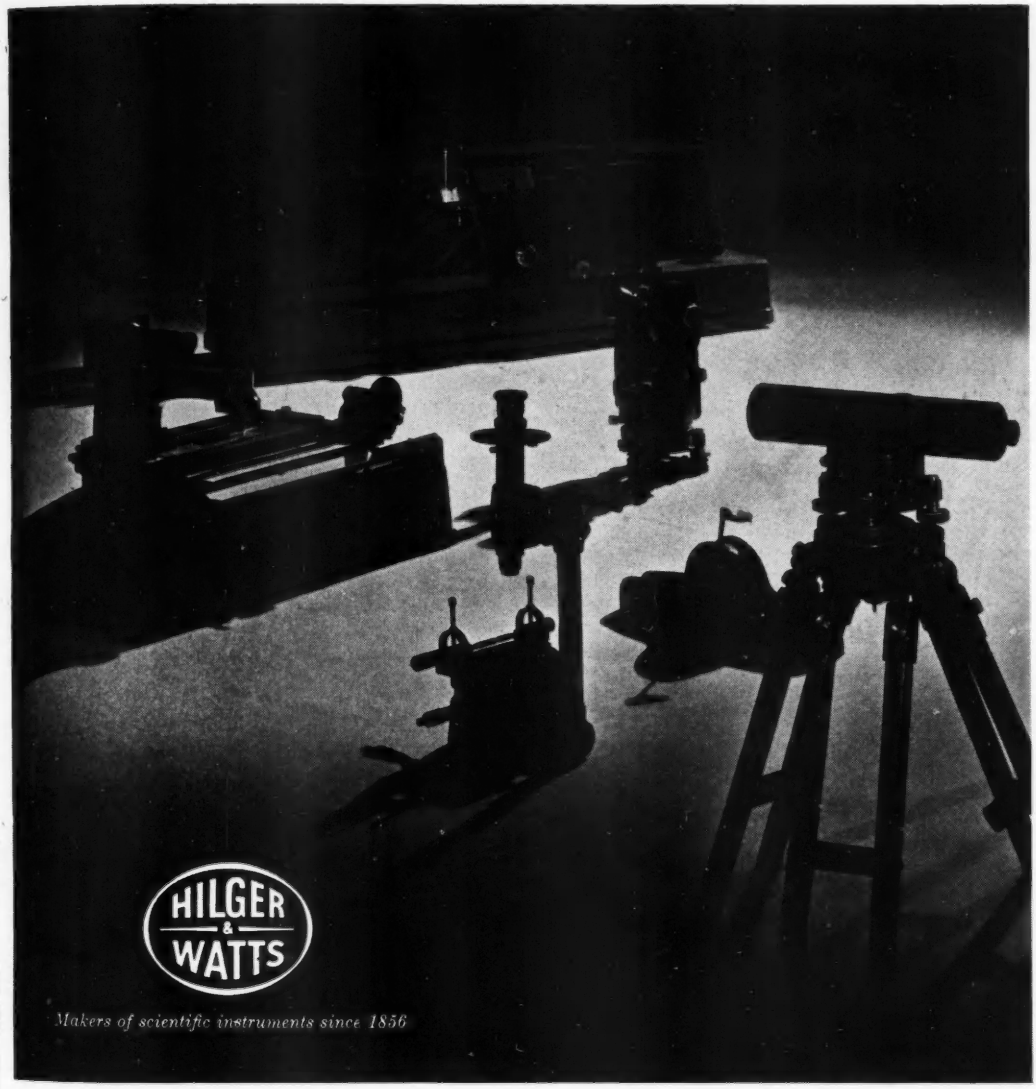

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that if you have anything to analyse, to measure, inspect, or survey, the people to help you are Hilger & Watts.

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HILGER & WATTS INC., CHICAGO 5, U.S.A

When hold-ups cost money-

. . . and ordinary lubricants have failed

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Lubrication of Heavy Lathe Centres with MoS_2

Workpiece: 42" diameter Paper Mill Drying Cylinder weighing approximately 2¼ tons, supported on 60 degree centres.

Problem: Each cut taken needed from 6½ to 8 hours. Various orthodox centre lubricants such as white-lead & oil, white-lead and graphite, grease & graphite, oil & graphite, etc., were tried. None of these were satisfactory. After about 40 minutes slight centre squealing began and after about one hour the job could not proceed without replenishing lubricant. To do this it was essential to support workpiece and wind out centre. In addition, damage occurred to centre, necessitating several removals for reconditioning.

As eight cylinders had to be machined, the above circumstances became quite intolerable.

Solution: A two-ounce tube of Rocol Anti-Scuffing Paste. When this lubricant was tried in accordance with the manufacturer's instructions it became possible to run the cylinder on centres for from 16 to 23 hours. In most cases, therefore, several cuts could be taken without interruption.

Conclusion: Only one two-ounce tube of Rocol Anti-Scuffing paste was needed for eight Cylinders. We regard this as a truly marvellous performance, and we are now using the paste as a standard centre lubricant for all kinds of work.

Director

March 1960

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Rocol ANTI-SCUFFING PASTE

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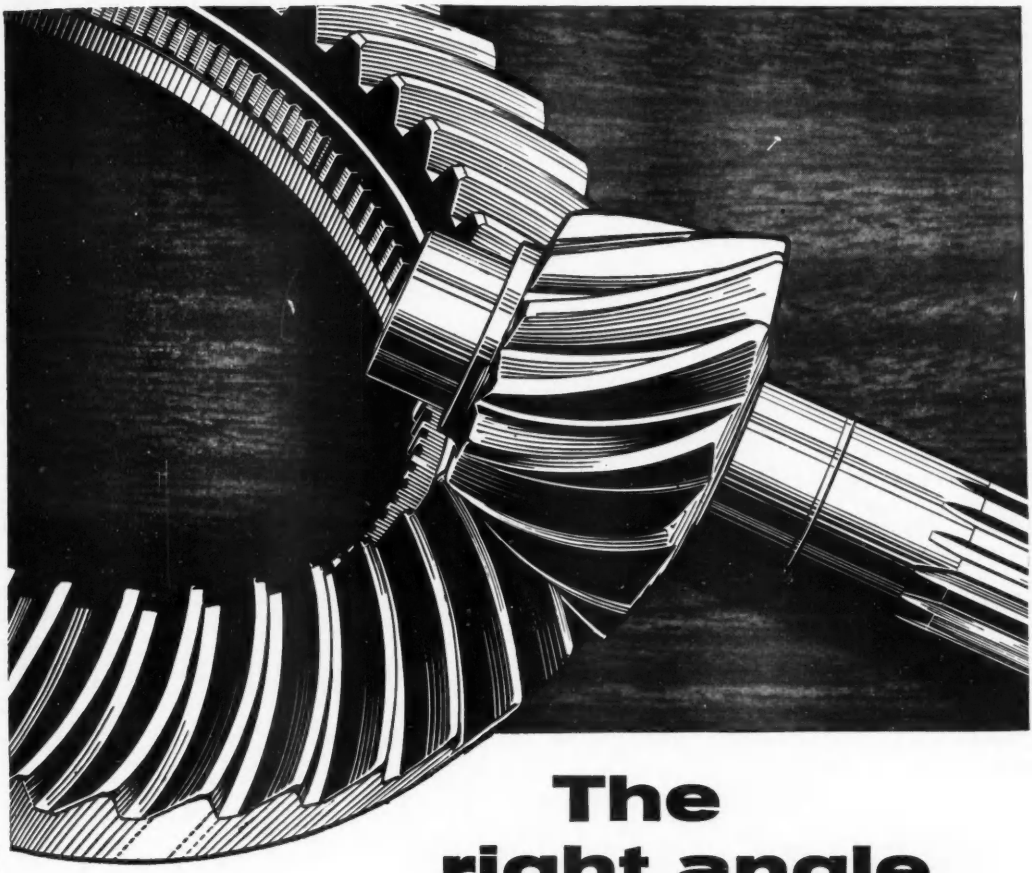
Rocol House, Swillington, Leeds. Tel: Garforth 2261



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E.N.V. are specialists in the design and manufacture of spiral bevel and hypoid gears, drives and assemblies, for which they have an exceptionally well-equipped plant.

E.N.V. engineers will be pleased to advise on problems associated with gears and drives, especially where bevel gears are used.

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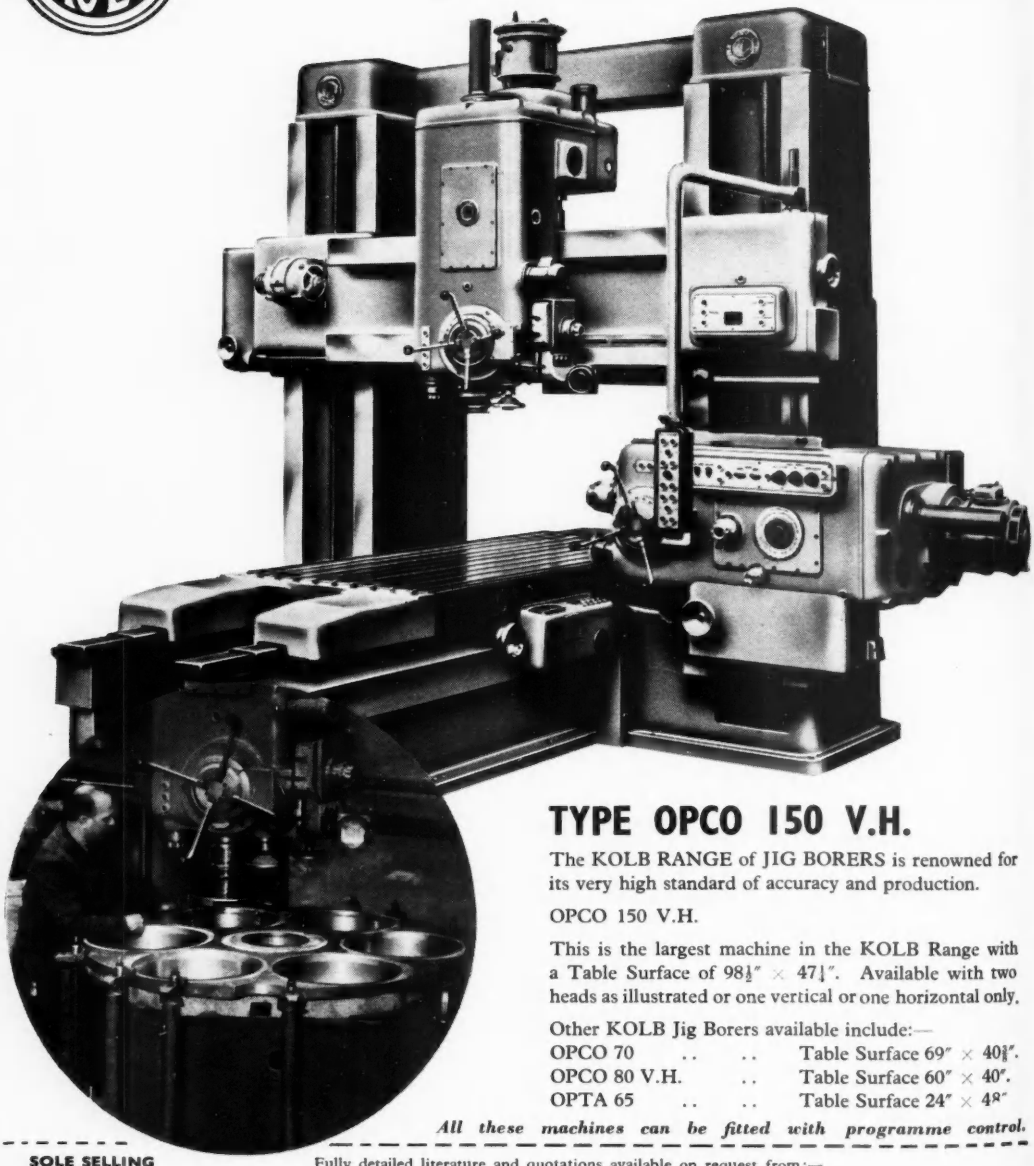
HIGH PRECISION OPTICAL JIG BORERS



TYPE OPCO 150 V.H.

The KOLB RANGE of JIG BORERS is renowned for its very high standard of accuracy and production.

OPCO 150 V.H.

This is the largest machine in the KOLB Range with a Table Surface of 98½″ × 47½″. Available with two heads as illustrated or one vertical or one horizontal only.

Other KOLB Jig Borers available include:—

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OPCO 80 V.H.	..	Table Surface 60″ × 40″.
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All these machines can be fitted with programme control.

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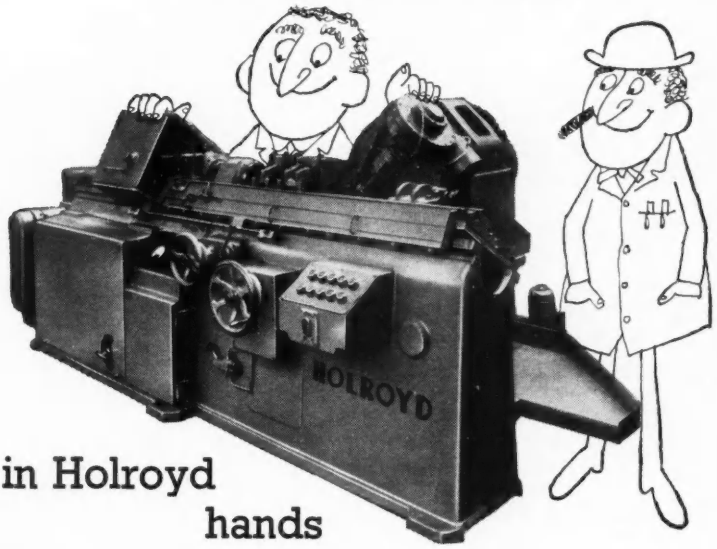

safely in Holroyd hands

If you have a big call on rotors it is worth remembering that our Rotor Manufacturing Section is completely equipped with unique machines of our own design and manufacture and that we now have a long experience in this very specialised field which might be of invaluable use to you. Our pioneer work in rotor manufacture has cleared the way for their increasing use with compressors, pumps, blowers and meters, and we can make them accurately to your design, either complete or from your prepared blanks.

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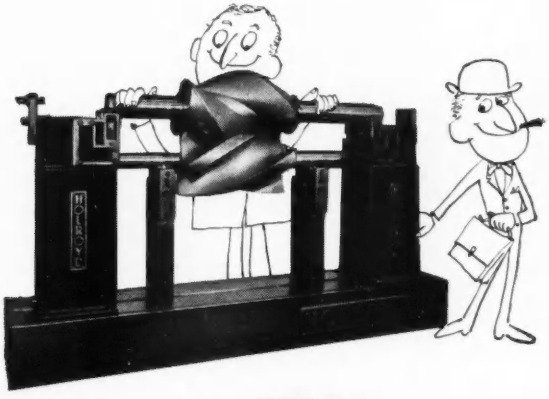
The biggest Holroyd machine can make rotors up to 32″ diameter and 50″ face. The smallest machine will go down to 1″. Helix angles can be anywhere between 30 and 60 degrees, with any combination in the number of lobes.



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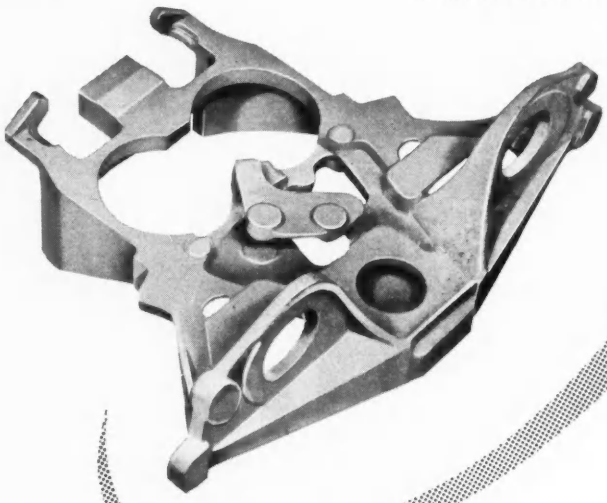
* The greatest technical experience augmented by quality control of production.



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Incorporating a patented Overload Preventer giving greater security and safety to the operator, also reducing wear and saving cost of maintenance. A free-wheeling feature enables quick adjustment of unloaded chains.

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SPRING-BALANCED CRANE FORK

A new concept in mechanical handling ... *faster* ... *safer* and *more manoeuvrable*. Replaces chains and 'C' frames. Can be used in gangways too narrow for fork-lift trucks; this means an increase of storage space of up to 50 per cent.

Available in a range of sizes and in capacities up to 5 tons.

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Short headroom. Lightweight. Compact for high efficiency. Capacities from 4 ton to 10 tons.

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Large capacity for use in confined spaces. Light enough for ONE MAN to use. Swaying under load eliminated by large diameter cylinder providing easy adjustment of height. Capacities from 10 to 30 tons.

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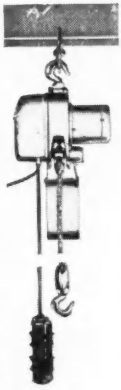
Entirely new design giving TWO SLINGS IN ONE. Sling legs lock automatically when lifting starts. Saves labour, time and accidents. Capacities from 1 ton to 20 tons.



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5 and 10-cwts. capacity. Light-weight, compact and portable. Push-button control. Upper and lower overtravel limit switches. Supplied for any height of lift to suit requirements. Top hook suspension facilitates fitting to travelling trolleys or girder clamps etc.

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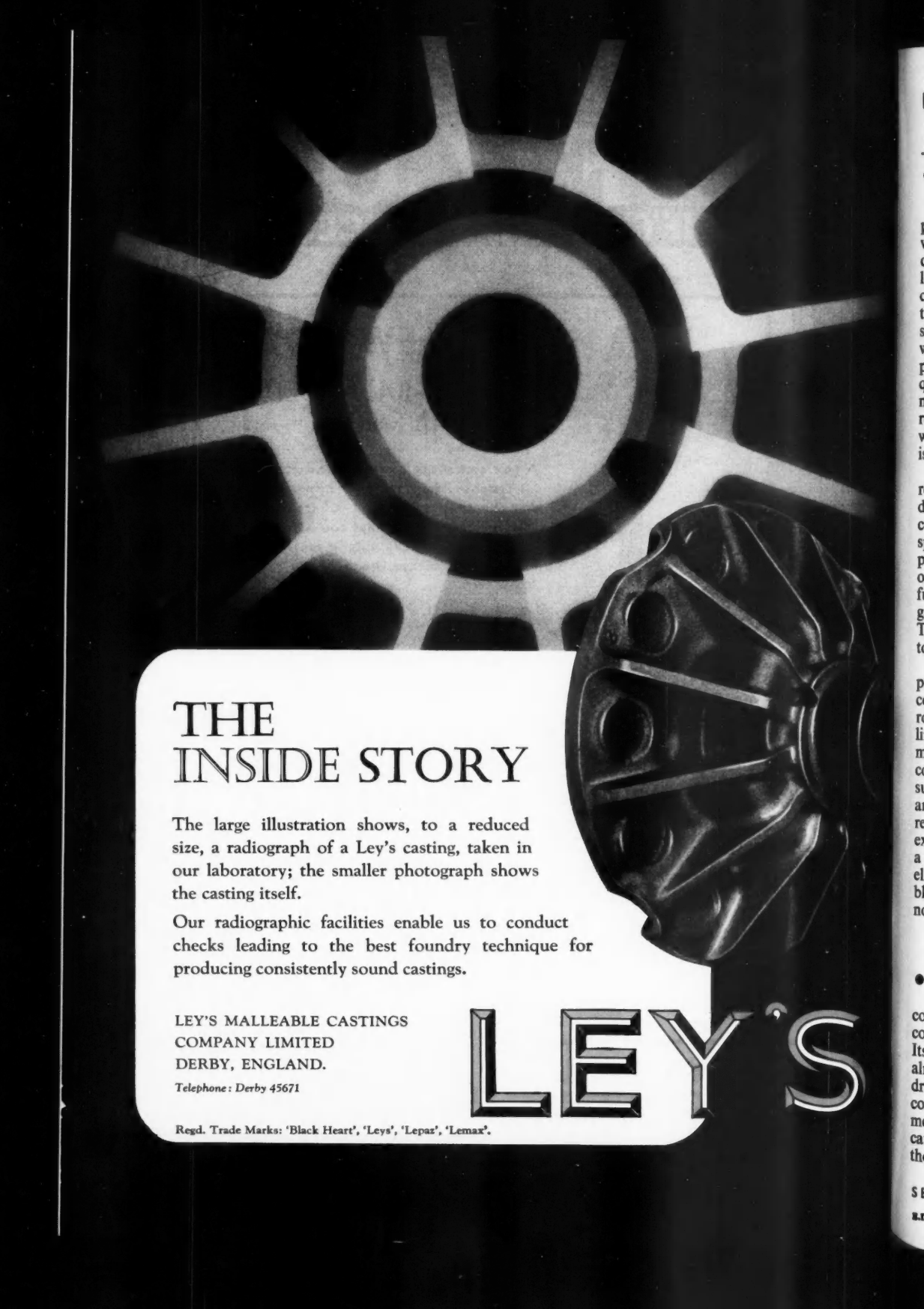

THE INSIDE STORY

The large illustration shows, to a reduced size, a radiograph of a Ley's casting, taken in our laboratory; the smaller photograph shows the casting itself.

Our radiographic facilities enable us to conduct checks leading to the best foundry technique for producing consistently sound castings.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *THERMO-BLOWER UTILIZING THE COANDA EFFECT*

When a stream of fluid under pressure passes through a slot which has a lip extended by a wall curving away from the fluid leaving the slot, the effect is to cause the stream to tend to follow the configuration of the lip and to induce some of the surrounding fluid to join the stream. This effect, which is known as the Coanda effect, makes it possible to set in motion and to direct a large quantity of ambient fluid by means of a small mass of fluid under pressure, and is used in a recently patented design of thermo-blower which has practically no moving parts and which is therefore a true static blower.

In this design, the blower consists of a receiver, from which gas under pressure is discharged through a Coanda slot to a passage communicating with the surrounding atmosphere through a convergent-divergent intake passing centrally through the receiver and opening into a chamber provided with a ring of fuel burners, so that the energy of the mixture of gas from the receiver and induced air is increased. The mixture is then discharged from the chamber to the point of utilization.

This static design of thermo-blower should possess a number of advantages. Thus, most conventional types of compressors include rotating or reciprocating components, thereby limiting their speed of operation and also the maximum permissible temperature in cases where combustion takes place, as they are subject to substantial creep at elevated temperatures. In any case, the maintenance of rotating or reciprocating components requires a certain expenditure of energy which may be regarded as a pure loss. These disadvantages are virtually eliminated in the new design of static thermo-blower, which, as already stated, has practically no moving components at all.

From *Brit. Pat. Spec.* 837,117.
Sebec Nouvelle S.A., Lausanne, Switzerland.

● *NEW MERCURY-POOL ARC TUBE*

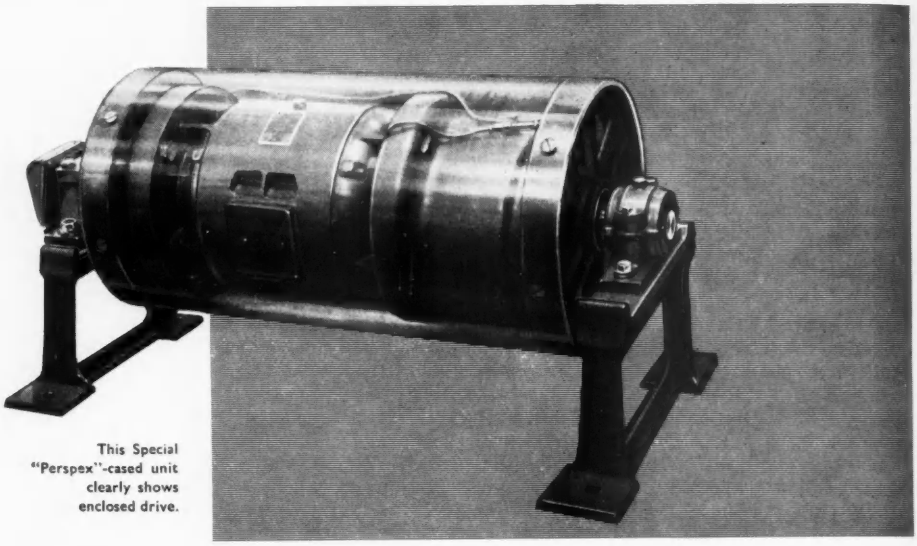
In certain respects the mercury-pool arc comes closer to the ideal of an electronically controlled switch than any other known device. Its resistance in the non-conductive state is almost infinite, withstanding voltages of hundreds of kilovolts. The anode voltage in the conductive state is very low, and can be measured in tens of volts, and the mercury-pool cathode is very rugged, allowing the passage of thousands of amperes of current. Transition from the conductive to the non-conductive state may occur within as short a time as 10^{-8} seconds. These properties, combined with long tube life, have made the mercury-pool arc a popular device for high-voltage and high-current switching applications, rectifiers, inverters, etc. The most serious disadvantage of the mercury-pool arc is the difficulty of arc initiation. Reliable starting methods require a large power input and expensive starting circuitry. This is particularly objectionable where high repetition rates of starting are required, such as in high-frequency inverters and pulse modulators.

To overcome these difficulties a new mercury-pool arc tube, designated "Empretron", has been developed, in which the arc between the mercury-pool cathode and the main anode is initiated by a vacuum spark. The spark discharge occurs between two continuously replenishable electrodes, one being an electrode partly immersed in the mercury pool, and the other, the starter electrode, a mercury reservoir supported above the mercury pool. Starting is accomplished by applying a high-voltage pulse to the starter electrode. The resulting spark discharge develops into an arc between the cathode and the main anode. Operation at repetition rates up to 5000 cps has been demonstrated, as compared with the upper limit of 400 cps for the conventional ignitron.

From *Communications and Electronics*, *A.E.I.I.*, U.S.A., May 1960, pp. 85–91.

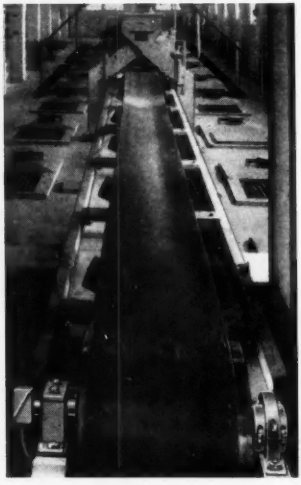
● *USE OF THE THERMITE REACTION TO PRODUCE REFRACTORY CERMETS*

Cermets have been produced in the past by using conventional powder-metallurgy techniques to form compacts composed of the desired ceramic and powdered-metal ingredients, these compacts being sintered at elevated temperatures, with the metal acting as the bonding medium of the system. In this connection, it is interesting to note that, during the past four years, Georgia Institute of Technology has been evaluating the thermite process as a means of producing cermets, making use of the high temperatures evolved from the thermite reaction itself, as well as of the reaction products. In this development, advantage is taken of the high heat available from the thermite reaction to form



This Special "Perspex"-cased unit clearly shows enclosed drive.

Here's the answer to your floor space problem!



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refractory cermets which could not otherwise readily be fabricated. The intensity of the thermite reaction, and thus the tendency of the phases to segregate, are a function of the reacting oxide of the active metal. In order to reduce this tendency towards phase segregation, a control or throttling agent can be used to consume some of the heat of the reaction, this control agent generally being provided by the products of reaction. Test bars of aluminium oxide/zirconium disilicide cermet were fabricated from a mixture of zirconium silicate, kaolin, and aluminium powder. Clay was used as a binder and lubricant for the dry-pressing operation and also served as an additional source of silica. The actual composition was a mixture of 85% zirconium silicate and 15% kaolin. Test bars, pressed in a steel die, were placed in a silica combustion boat, which was filled with magnesium oxide powder, This, in turn, was wrapped with a double layer of kaolin wool. The test bars were then placed in a furnace which had been preheated to 1800° F, and allowed to remain in the furnace for one hour, when the thermite reaction was complete. Transverse strengths in excess of 10,000 psi and tensile values in excess of 5000 psi were obtained both at room temperature and at 2200° F.

From *Ceramic Age*, U.S.A., June 1960, pp. 39–45.

● *TORSIONAL VIBRATIONS IN SYNCHRONOUS-MOTOR DRIVES*

Certain component failures in synchronous-motor-driven high-inertia rotating equipment have been the source of great concern to rotating-equipment manufacturers. A typical example is the failure of the shaft of a centrifugal compressor driven by a synchronous motor. Investigations have shown that salient-pole synchronous motors, when started without field excitation as induction machines, exhibit a pulsating torque. The torque pulsation frequency is equal to twice the slip frequency, which varies from line frequency at zero speed to zero slip at synchronous speed. In most of the literature available on synchronous-motor starting, the pulsating effect is ignored and only the average torque figures are given. This is misleading in that, when a synchronous motor is to drive high-inertia loads, the potential problems caused by the pulsating component are not evident.

To solve the torsional frequency problem, several remedial measures are available. For instance, it is possible to ascertain where the resonance point occurs when superimposed on the motor starting curve. Once this has been determined, the system may be retuned to shift the resonant frequency. The relocation of resonance may be in such a direction as to move to a more favourable point of accelerating torque so as to reduce the time in resonance. An alternative is to move to the point where the direct-axis torque curves cross the quadrature-axis torque curve. At this point there is no excitation force for resonance and it is therefore an ideal point at which to locate the natural frequency. Yet another alternative is to change the motor-field discharge resistor to modify the motor curve. The method of changing couplings in order to modify overall shaft stiffness gives only a limited amount of latitude.

From *Trans. ASME, Journal of Engineering for Power*, U.S.A., July 1960, pp. 215–220.

● *UNIFORM TWO-WAY ORIENTATION OF PLASTIC FILMS*

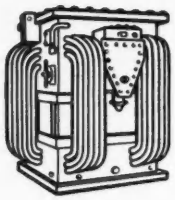
In the production of thin plastic films, an important factor is the nature and extent of molecular orientation. Orientation is achieved by hot-stretching or cold-stretching of the film at some stage of manufacture. The physical properties of the final plastic film are very sensitive to the molecular orientation, so much so that, for example, unoriented polystyrene film is brittle and fragile, whereas the same material, when properly oriented, is strong and tough. If the orientation is in one direction only, the plastic film will have different properties in different directions. For this reason, as pointed out in a recent paper, it is often desirable to impart equal molecular orientation in all directions within the plane of the film. This implies a film-stretching step in which the film is subjected to equal longitudinal and transverse stretching, requiring the establishment of a highly specific geometric flow pattern in the stretching zone. This flow pattern involves diverging radial flow lines, the velocity at any point being directly proportional to the distance from the convergence point of the flow lines.

These geometrical facts lead to certain design requirements for a machine suitable for the production of plastic film with uniform two-way orientation. In order for new concepts to be expressed in terms of practical working designs for machinery, mechanical development is required, and the reduction to practice of this concept is outlined in the paper.

From *Trans. ASME, Journal of Engineering for Industry*, May 1960, pp. 167–172.

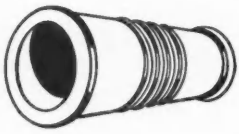
● *NEW ECONOMICAL STEEL-MAKING PROCESS*

In a new patented process, designed to combine the manufacture of steel from pig iron and to recover iron from reduced iron ore, an electric furnace is charged with at least 20% by weight of liquid pig iron, covered with a solid layer of steel scrap in which iron ore and slag-forming additions are embedded in localized regions below the furnace electrodes. In operation, the arcs from the electrodes rapidly melt the scrap



from transformers

to bellows



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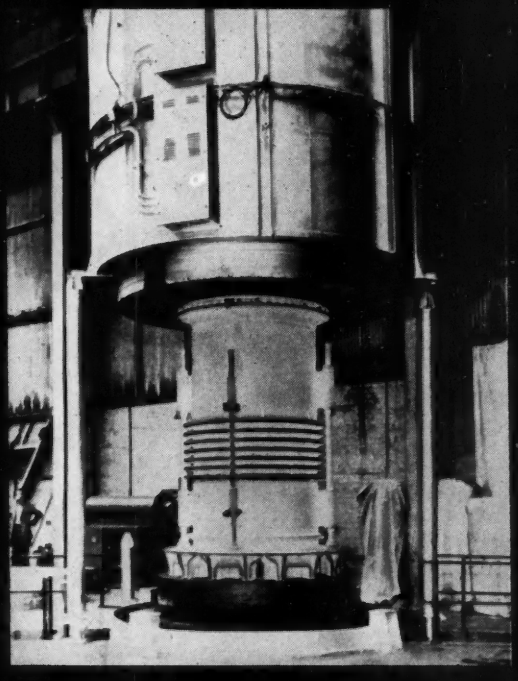
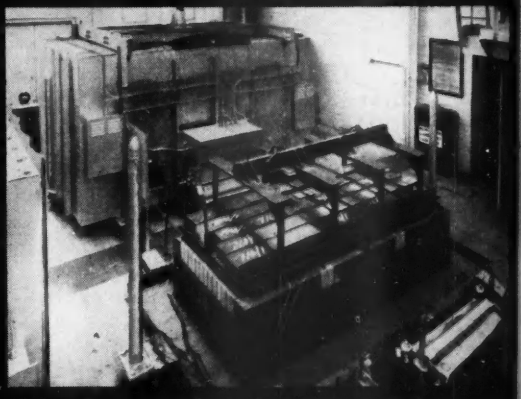


Cylindrical bell furnace, probably the largest in Europe, for the heat treatment of bellows type flexible pipes, normalising at 975° C, tempering at 690° C, and stress relieving at 600° C.



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lying in their immediate vicinity. They thus tend to establish contact very quickly with the liquid pig iron present in the hearth of the furnace. In this way, the craters are formed very easily in the solid charge, and are closed off at the bottom by the surface of the liquid pig iron. The more easily the steel scrap melts, the more rapidly will the craters be formed.

A particular advantage of this process is that the reduction of iron ore takes place in confined spaces which, in effect, form melting pots. In these pots, the heat produced by the arcs is concentrated in a relatively small space. Since the bottom of these pots is in direct communication with the liquid pig iron, refining of the pig iron and reduction of the iron ore take place much more rapidly than usual and with much less expenditure of heat. The craters widen only gradually, because heat flows away to the pig iron. Even though this is not a continuous process for the production of steel, its great significance lies in the feature that a considerable proportion of the iron required for the manufacture of the steel is derived directly from the ore.

From *Brit. Pat. Spec.* 836,342.
L. von Roll'sche Eisenwerke A.G., Gerlafingen, Switzerland.

● *OIL TRANSFER BY ROTATING DISCS*

The supply of oil to journal and thrust bearings for hydrodynamic lubrication is an important problem in bearing design. Although the use of ring-lubricated bearings is restricted to stationary machines having horizontal shafts, many advantages, i.e., simplicity, reliability, great oil economy, cheap manufacture, and saving in power are obtained, in comparison with forced-feed lubrication. Consequently, great emphasis has been given to ring-lubricated bearings, and their performances have been carefully studied by several investigators.

On the other hand, very little published information is available on ring lubrication. A recent investigation is therefore concerned with the experimental and theoretical study of the oil-transfer characteristics of plain discs. Tests were carried out with steel discs of 100 mm, 150 mm, and 200 mm diameter with different widths. These discs were keyed to a horizontal drive shaft mounted on ball bearings and driven by a Ward-Leonard unit through a flexible coupling, the speed being variable between 30 and 3000 rpm. An oil scraper-collector was used at the top position of the discs to collect the oil transferred by the disc from the oil bath. The results of these experiments indicate that (1) with discs of the same width and the same depth of oil immersion, oil transfer increases as the disc diameter is decreased; (2) oil transfer increases linearly with the width of the disc; (3) oil transfer increases with the depth of immersion, this effect being particularly pronounced at high speeds; and (4) oil transfer increases with increasing viscosity. By presenting the influence of these variables and their correlation in graphical form, it is claimed that the oil-transfer capacity of rotating discs can easily be obtained for different operating conditions.

From *Bulletin of the Technical University of Istanbul*, Turkey, Vol. 12, 1959, pp. 1–14.

● *NEAR-PERFECT LIGHT AMPLIFIER*

A small electronic tube, known as an "Astracon", is said to reach the near-ultimate in the ability to amplify ordinary light. The tube, which operates on an amplifying principle discovered some years ago, is so sensitive that it makes visible a single electron released at the input of the tube by an individual photon. The image of an object, which is so dim as to be invisible to the naked eye, is focused by lenses onto a light-sensitive screen, i.e., the "photosurface", placed at the input end of the tube. The individual particles of light, or photons, arriving from the object strike the surface and eject electrons from it. Each ejected electron is then accelerated forward by 2000 V and impinges upon a thin two-layer film, which is only a few millionths of an inch thick. The front surface of the film is aluminium, while a slightly thicker layer of an insulating material is deposited on its rear surface. When a high-speed electron enters the film, it penetrates into the insulator and releases four or five additional electrons. These are accelerated in a second film, or "dynode", where electron multiplication is repeated. By using five such steps, a single electron is multiplied to about 3000 electrons, these being given a final 20,000-V boost and projected into a thin layer of fluorescent material at the ouput end of the tube, where they release 20,000 or more photons of visible light, reproducing the dim, invisible image received at the input end. In nuclear physics, this tube will, for the first time, permit the viewing of the tracks of high-energy cosmic rays and other particles.

From *Westinghouse Engineer* U.S.A., July 1960, p. 128.

● *TECHNIQUE FOR MAKING SUPERCONDUCTIVITY VISIBLE*

A new technique has been developed to make superconductivity visible, so that the transformation between normal and superconducting states can be observed. It has already permitted both observation of previously unexplored phenomena and more rapid and complete study of known phenomena. In particular, this technique has provided data about the motions of normal and superconducting domains that

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could not be observed before. It has also provided a fast and accurate method for measuring basic magnetic properties of superconductors.

The method is based on the principle that a sufficiently strong magnetic field is capable of changing a material from the superconducting to the normal state. However, as long as the material remains superconductive, it is a perfect magnetic insulator. The specimen to be observed is usually prepared in the form of a flat disc, upon which is placed a plate of special cerium phosphate glass, about 0·01 inch in thickness. When magnetized, this type of glass has the property of rotating the plane of polarized light. A beam of monochromatic polarized light is beamed onto the glass, and the reflected light is viewed through a polarizing filter that can be rotated to any desired angle. The portions of the glass plate directly above the superconductive areas are shielded by them from the magnetic field, so that these portions of the glass are not magnetized. On the other hand, the magnetized portions of the glass rotate the plane of polarized light reflected by them. By adjusting the polarizing filter through which the reflected light is observed, the magnetized portions of the glass can be made to appear dark, and the unmagnetized portions to appear light, thus revealing the pattern of superconductivity.

From *Electronics*, U.S.A., July 22, 1960, pp. 76 and 78.

● *NUCLEAR GAS-TURBINE PLANT*

In a recently patented process for converting nuclear energy to mechanical energy, a gas containing fissile material is compressed from an originally subcritical to a critical degree, and is then passed through a nuclear reaction zone which contains sufficient moderator, e.g., graphite blocks, to achieve a nuclear reaction in the gas, resulting in an appreciable increase in its enthalpy. The gas is then expanded in a turbine, and the exhaust gas cooled for recycling by extracting waste heat in a heat exchanger. At the compressor inlet, a temperature of 290°F and a pressure of 215 psi is envisaged, the condition at the inlet to the nuclear reaction zone being 900°F and 3000 psi, and the temperature at the turbine inlet 1050°F. It is claimed that, in this system, much higher gas temperatures can be achieved than hitherto possible, without damaging materials in the system.

The preferred gaseous fuel is hexafluoride of uranium 235, which is mixed with a diluent gas, preferably stable to radiation and heat and of low density, such as helium, hydrogen, or deuterium. The diluent gas can have some moderating properties, but should not supply the total amount of moderation necessary to create a critical reaction mass. A reflector can be used around the nuclear reaction zone to help conserve neutrons, and can be gaseous, liquid, or solid, though solid reflectors are preferred, e.g., carbon, beryllium, or beryllium oxide. In many cases, the reflector and moderator can be the same.

Proposed uses are the propulsion of ships, locomotives, or aircraft. Generally, the system may be useful as a replacement for gas turbines of the conventional type.

From *Brit. Pat. Spec.* 841,972.
Esso Research and Engineering Co., Elizabeth, N.J., U.S.A.

● *INFLUENCE OF STRESS-REPETITION FREQUENCY ON HIGH-TEMPERATURE FATIGUE*

A recent report refers to rotating-bending fatigue tests under constant strain amplitude with a 0·55% carbon steel and a 13% chromium steel. The object of these tests was to study the influence of stress-repetition frequency on fatigue strength. The test temperature was varied from 450 to 700°C, and the frequency of the stress cycles was varied from 170 to 1500 cycles per minute. In previous experiments concerning the frequency characteristics of a low-carbon steel at elevated temperatures, an influence of strain ageing was noted at 300°C, and elevated-temperature fatigue characteristics appeared at 450°C. At 300° C, the higher frequency resulted in fewer cycles to fracture, because of strain ageing due to the anchoring of dislocations by solute atoms. At 450°C, under a definite strain amplitude, fracture occurred at about the same number of cycles, irrespective of frequency, in the range of large amplitudes, while a lower frequency resulted in fewer cycles being required to fracture in the range of small amplitudes.

In the case of the 0·55% carbon steel, the influence of strain ageing seemed to appear at a temperature of 450°C. At 550°C, the elevated-temperature characteristics appeared which in the case of the low-carbon steel had been observed at 450°C. In the case of the 13% chromium steel, any influence of frequency on the number of cycles to fracture was not observed at 450°C, and elevated-temperature fatigue characteristics appeared at 600°C.

From *Bulletin of the Japan Society of Mechanicol Engineers*, May 1960, pp. 235–241.

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VOL. XXI No. 9 SEPTEMBER, 1960

Method of Calculating the Cost of Energy Losses in Electricity Supply Systems

By A. P. MACKERRAS and J. B. KIRKWOOD

From *Electrical and Mechanical Engineering Transactions*,
The Institution of Engineers, Australia,
Vol. EM 2, No. 1, May 1960,
pp. 21-27, 4 illustrations.

THE prime objective in the design of an electricity supply system is to provide an adequate and reliable supply of electricity at minimum cost. In order to achieve this objective, a realistic evaluation of the future costs of the energy and power consumed by losses and by auxiliary equipment is required. Such costs are used in making selections from among alternative designs, so that the sum of the financial charges on capital expenditure and the cost of providing the power and energy consumed in losses and auxiliary plant will be a minimum.

Typically, in the selection of the size of conductor for a transmission line, the size of fan for a cooling tower, or the optimum level of losses for a transformer, it is known that the power and energy consumed in the equipment may be reduced at the cost of additional capital expenditure. The optimum selection will be made when the savings associated with such reductions in power and energy consumption are just counterbalanced by their increased financial charges on the capital cost.

The determination of the true cost of losses and of auxiliary power requirements presents some difficulty, and various opinions have been expressed as to how these costs should be calculated. Even when the method of calculation is agreed upon, there are complications arising from the development of the electricity supply system, improvements in operating efficiency, the introduction of hydroelectric power, and other changes which may affect the cost of losses during the useful life of the apparatus for which the losses are to be evaluated. An attempt has therefore been made in this paper to give a realistic, workable, and reasonably accurate solution to the problem. The determination of the cost of reactive power losses will not be dealt with.

Fundamentally, the cost of losses in a particular piece of equipment is equal to the total cost of supply of power and energy to the system, minus what the total cost of supply would have been if these losses had not been incurred; thus, it is the *incremental* cost.

Losses are not supplied by separate small generating units. Rather, the losses are included as part of the total system demand when load forecasts are made, and consequently they alter the overall system costs only to the extent to which they intermittently influence the date of installation of items of plant and transmission works, and cause any differences in the total cost of generation. As a result, the cost of losses could be determined by estimating the form of future system development, both with and without the losses, and by calculating the difference in operating and other costs.

The calculation of the cost of losses in this manner for individual pieces of equipment would not be practical. Furthermore, because the losses associated with any particular apparatus are small in comparison with the size of generating units employed for the expansion of the system, the results obtained would be extremely variable. In some cases, no differences in construction requirements would result from an increase in losses, while in others it would be necessary to install an additional generating unit or to build a new transmission line at a cost out of all proportion to the losses in the apparatus concerned.

To avoid these difficulties and to ensure a consistency in the cost assigned to losses, it is preferable to determine unit costs which may be employed to calculate the cost of losses associated with any particular apparatus. These unit costs should first be calculated for a particular year in the near future for which load forecasts are available and for which system plans have been made and costed. This calculation should be repeated for other selected years for which the necessary data are reasonably accurately known. Trend curves may thus be prepared and used to fill in the gaps and to extend the values over the life of the apparatus being considered. Present worth-factors must then be applied and the aggregate present worth of the losses found. For years further in the future, the values will become more speculative, but their significance will be reduced by the lower present worth-factors applicable.

The cost assigned to losses is not merely of academic interest, but has a significant influence on system development. If the cost of losses is assigned too high a value, the tendency will be to produce a system with low losses and therefore high capital expenditure; if the cost of losses is calculated on a basis which is unsound, then an electricity supply system will develop which is not the most economical.

Cost of Losses in an All-Thermal System

There are three components of cost incurred by system losses, these being (1) cost of energy loss, i.e., the cost of generating and transmitting the energy lost in the apparatus considered, (2) the annual cost of "loss plant", i.e., the annual fixed cost of plant assumed to be installed to meet the increase in the maximum demand on the system caused by the losses, and (3) savings due to operation of loss plant, which, once installed, will be operated for maximum overall economy. Normally, the

loss plant will be of modern design and low operating cost, and it will therefore off-load higher-cost generating plant on the system. In other words, the existence of losses at the time of the system peak load results in the earlier installation of new generating plant which leads to system operating economies. If desired, component (3) may be regarded as part of component (2), as they both result from the installation of the loss plant.

Cost of Energy Loss:—

The true cost of energy loss is the saving in the total cost of generation which would result if the loss could be eliminated. It is therefore equal to the weighted average cost of supplying the last increments of load from hour to hour during the day, such increments being of a magnitude comparable with the system losses.

A satisfactory approximation to the cost of supplying these increments of load may be obtained by determining, for all periods of the day, the overall running cost of the plant which would be in service to supply the system load, including losses, together with the desired level of spinning reserve. This cost would include fuel, plus operation and maintenance associated with the generating units brought into service at each period. Similar costs should then be obtained with the system load throughout the day, reduced by a constant amount comparable in magnitude with the total system losses. The difference between these running costs will represent the cost of supplying the incremental load, a cost which will vary from hour to hour, depending on the generating plant in service. It has been found that high-speed digital computers provide a satisfactory method of simulating system operations for the determination of the cost of supplying increments of system load. The values may be predicted with satisfactory accuracy for a few years ahead, but after that they naturally become more speculative.

In studies of engineering economics, the energy losses in the apparatus concerned would be estimated for various time intervals during the day on the basis of loading forecasts, and, having determined, as above, the system incremental costs for each of these intervals, the total generation cost of supplying the losses can be found. Allowance should, of course, be made for the transmission losses which will occur between the power station and the apparatus. A reasonable estimate of these losses should be available from network studies in the planning of the transmission system, and a forecast of changing values over the life of the apparatus should be used.

Annual Cost of "Loss Plant":—

Losses in any apparatus, and in the supply system generally, will increase the system peak demand by the amount of these losses. It is not the maximum value of the losses, but their value at the time of the system peak load which is important, since this is the value which influences the date of installation of the next generating unit. Similarly, it is the value of the losses at the time of the peak load on the transmission system feeding them which influences the date of installation of the next transmission line or substation.

These increments of load must, in general, be supplied by "firm" plant, so that a due proportion of reserve rating must be allowed. Generating-plant auxiliaries and unit step-up transformers are an exception to this rule, however, as they are, in effect, an integral part of the generating plant. The electricity consumed in these items may be regarded as being supplied from the generator itself, and will require power only when the generator is running.

As previously discussed, losses are not supplied by special small generating units, nor are they generally of sufficient magnitude to influence the size of generating units selected for expansion of the system. Rather, the effect of losses is to advance the date at which new generating plant and transmission works must be installed. This is equivalent to compressing the time scale of the programme for system development, and the additional capacity thus made available to provide for the system losses is consequently the plant of most recent design, and frequently the lowest cost per kilowatt.

The extra capacity provided in this manner will not always be exactly equal to the losses plus the associated reserve. However, a number of programmes of system development have been examined and it has been found that on average the losses plus reserves and the loss plant are of very similar magnitude. The results of a typical study are shown in Fig. 1, from which it will be seen that, although there are fluctuations in the amount of loss plant available, on the average the agreement between the loss plus reserves and the plant provided is satisfactory.

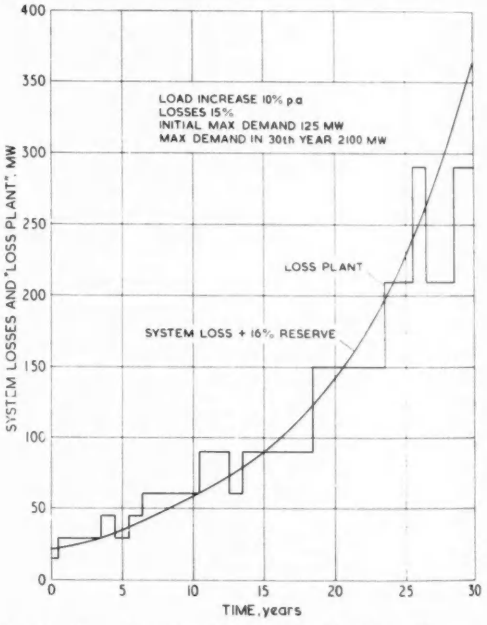


Fig. 1. Comparison of typical "loss-plant" and actual system losses plus reserve.

As the effect of losses is to advance the date when the next generating unit must be installed, and eventually the date when a new power station must be started, it is necessary to include allowance for site purchase and such site work as will be sufficient for the station when fully developed. Consequently, the capital cost per kilowatt used for the loss plant in any year should be the average cost per kilowatt of the generating stations being constructed at that stage of system development.

Similarly, the cost per kilowatt of the appropriate part of the transmission system must be estimated from plans of future extensions. Here again, the increment of peak loading on the transmission, subtransmission, and

distribution systems due to losses advances the construction programme for each portion of the system. In general, the times of peak load will be different on the transmission, subtransmission, and distribution systems. These items should be calculated separately if the additional labour involved is justifiable.

For losses within the power station, or in the high-voltage transmission system linking a station with the main portion of the supply system, the required cost of loss plant should include the power station, switchyard, step-up transformers, and the required components of the transmission system. Losses in this part of the system do not have any significant effect on the time of replacement of subtransmission and distribution works, and no allowance should be included for these latter items. For losses in other parts of the system, the loss plant should generally include all plant up to the point at which the losses occur, but not beyond this point.

Savings due to Operation of Loss Plant:—

When the generating plant required to supply the losses at the time of the system peak load has been installed, it will naturally be used to the best advantage and not reserved to supply losses only. Provided that the proportions of the various types of plant are in proper economic balance, approximately the same overall cost would be assessed for the loss plant, whether the current installations are base-load coalfield stations or metropolitan peak-load stations, because the changes in the annual cost of loss plant and the savings due to its operation would tend to offset one another.

The saving in generation costs due to the operation of loss plant is equal to the total cost of fuel, operation, and maintenance if the loss plant had not been installed, minus the same items of cost with the loss plant installed and operating to produce maximum overall economy.

Assuming the generating plant required to supply the losses is part of a base-load station, it will run at full output during all the hours it is available. If it had not been installed, the same energy during the same periods would have been generated by the highest-cost plant in operation for each period, because this is the plant eliminated from service by the introduction of the new generating plant. The saving effected by the loss plant is therefore the difference between the cost of generation by the loss plant operating at full load during its hours of service and the cost of generating the same energy at system incremental cost.

This saving is dependent on the system load factor, which affects the value of the system incremental cost, but is not dependent on the load factor of the losses responsible for the installation of the loss plant.

Cost of Losses in an All-Hydroelectric System

In an all-hydroelectric system, the influence of losses is similar to that in a thermal system in that their occurrence increases the effective system demand, and this accelerates the dates by which new power schemes must be developed. Consequently, as for the thermal system, losses should be costed on the basis of the schemes assumed to be most recently placed in service as each future year is considered throughout the period for which the loss is being evaluated.

The components of cost already discussed as applicable to a thermal system are not amenable to definition when applied to an all-hydroelectric system. Thus, the cost of energy loss and the annual cost of loss plant are merged, because the costs associated with both capacity and energy output are largely incurred at the time that the scheme is being built. Savings due to operation of loss plant do not exist in this case, because the annual energy output of a hydroelectric scheme does not normally change during the life of the scheme but is fixed at the time the scheme is constructed by the water estimated to be available to it each year.

In assessing these costs, it is necessary to consider the most recent development as a whole, and not confine attention to a single hydroelectric plant forming a part or stage of such a development. Considering such an overall scheme, the cost of energy losses should be evaluated from the energy involved in the loss and the average cost per kilowatt-hour of the hydroelectric scheme based on the total of all costs associated with the scheme. Such an average energy cost includes both the cost of energy loss and the annual cost of loss plant. However, in general, an adjustment will be required, because the ratio of the energy in the loss to its kilowatt requirement at the time of peak system demand will normally be different from that for which the hydroelectric scheme was designed, and to which the average energy cost applies. This cost adjustment corresponds to an addition or subtraction of kilowatt capacity calculated at the kilowatt incremental rate for the hydroelectric development as a whole, and includes the incremental cost of varying the size of penstocks, pressure tunnel, tailrace, power station, generating units, switchgear, and transmission.

In an all-hydroelectric system, both the cost of energy loss and the annual cost of loss plant should be increased to provide for reserve requirements of the system.

Cost of Losses in a Combined Hydro-Thermal System

In a combined hydro-thermal generating plant, the procedure for the evaluation of losses is closely allied to that of an all-thermal system. For a combined hydro-thermal system, the variation of incremental cost during the day and for the various seasons of the year will be dependent on the costs of thermal-plant operation and on the way in which water available to the hydro plant is used. These operations will be integrated for maximum economy of the system as a whole.

The values of the system incremental cost of thermal generation will normally be required for planning purposes and these should be used to calculate the cost of energy loss. It is assumed that all energy available from hydro plants may be economically utilized and that the hydro-plant operation is sensibly independent of system losses. Run-of-river hydroelectric plant would generate according to water flow, while storage hydroelectric plant would operate so as to supply a fixed number of kilowatt-hours, as determined by the safe draw-off from the reservoir. Therefore, the additional energy brought about by losses must be supplied by the thermal plant of highest operating cost, because all lower generating cost plant would have already been given priority of loading.

The determination of the cost of loss plant will be based on the type of generating plant which will be installed at the stage of development being considered. Over any period of several years it is probable that new plant will be partly thermal and partly hydro, and a weighted-average cost may reasonably be used. The same reasoning will apply to the savings due to operation

of loss plant. However, since the design capacity of the hydro scheme and the rate of installation of the two types of generating plant will be integrated for maximum economy, it may be expected that the combined effects of the cost of loss plant and the savings due to its operation will be very similar for either the hydro or the thermal plant which is currently being installed.

It is appropriate that hydroelectic plant should be charged at the overall cost per kilowatt, including both headworks and generating plant. The consequent high cost of loss plant will, however, be substantially offset by high savings due to operation of loss plant, since the operation and maintenance costs of hydro plant are very small, compared with the corresponding fuel, operation, and maintenance costs for the older steam plant which would be off-loaded by the new hydro plant.

For thermal plant, both the cost of loss plant and the savings due to its operation will be smaller. However, their combined result should not be very different from that obtained for hydroelectric plant, since the system is assumed to have reached an economic balance between steam and hydro developments. Thus, the combined effect of the cost of loss plant and the savings due to its operation should not be very sensitive to the proportions assumed for thermal and hydro plant.

Special Considerations

In calculating the cost of power and energy consumed in electrical losses and auxiliary equipment in electricity supply systems, mention should also be made of a number of special considerations in connection with losses in short-period projects, comparisons with cost allocation for tariff purposes, and the cost of losses for bulk-supply consumers.

Losses in Short-Period Projects:—

Short-period projects frequently arise; for example, if the construction of a high-voltage transmission line is deferred for one year, the financial charges on the line are saved for that year, but additional losses are incurred. Clearly, the additional energy of the losses must be generated in accordance with the cost of energy loss. It is not realistic, however, to charge the cost of the loss plant and the savings due to its operation to the losses, because the construction programme would not be altered on account of such a short-time change.

With a long-term project of, say, 10 years, there is ample time for the additional losses to be reflected in the system load forecasts and in the resulting construction programme. Consequently, loss plant should be charged against these losses. The border line might reasonably be taken as the period of firm contracts and plans.

Comparisons with Cost Allocation for Tariff Purposes:—

The average incremental generation cost and the average annual cost of the required incremental plant would normally be used to determine the realistic cost of losses. This is, however, a different problem from the allocation of the total cost of the supply to different classes of consumers to act as a guide in drawing up a tariff schedule. The techniques which have been developed for the allocation of costs to the different classes of consumers are designed to provide an equitable division of total system costs, whereas the cost which should be assigned to future losses in order to minimize future overall system costs is the incremental cost associated with any change in future system demand and energy requirements which might result from a difference in level of system losses.

Cost of Losses for Bulk-Supply Consumers:—

Where a bulk-supply consumer purchases electrical power and energy for distribution and resale, an additional problem arises. Assuming that a local council purchases in bulk from a generating authority on a maximum demand tariff, the local council's engineer would calculate the value of losses in his distribution system on the basis that (1) energy losses, corrected back to the supply point, would be charged at the energy rate of the tariff, and (2) the power loss at the time of the purchaser's peak load, also corrected to the supply point, would be charged at the maximum demand rate of the tariff.

The result of this calculation would give the additional payment which the local council would have to make to the generating authority because of the particular loss being considered in the purchaser's system. It would not, in general, be the cost to the generating authority of supplying these losses.

If the cost of the same losses in the local system were to be calculated by the generating authority, the method proposed in this paper should be used, and the result would probably be substantially different. Thus, the former method of calculation is correct from the local engineer's point of view, provided that he can estimate the bulk-supply tariff appropriate to the years in the future during the life of the particular piece of apparatus for which he is evaluating losses. The latter method, as described in this paper, would be correct from the point of view of the supply authority, and would be the real cost to the community as a whole, on a long-term basis.

Accuracy of Method of Calculation

The method of calculating the cost of losses presented in this paper is believed to be sound in principle and practical in application. It is realized, however, that a considerable amount of arithmetic is involved, and it may be questioned whether the labour required is justified by the accuracy aimed at, in view of uncertainty in the accuracy of the data, which are essentially a forecast, and the fact that the cost of losses may not be a critical factor in a decision between one or other standard size of equipment to be chosen or in the acceptance of a tender.

On the other hand, the following considerations should be borne in mind:—

(1) The method proposed is clearly capable of many reductions in calculation without sacrificing the soundness of the principles involved, though naturally there will be a consequent loss of accuracy.

(2) Most of the data, e.g., future incremental and average generation costs and annual financial charges, must be determined for general planning purposes. Lack of accuracy in such forecasts is inevitable, and is no justification for departing from a method which is sound in principle. Thus, historical costs should not be used on the ground that estimates of future costs may be inaccurate.

(3) The unit costs of losses must be used in many calculations for a wide variety of purposes, so that a reasonable attempt at accuracy is desirable. Furthermore, these values need to be recalculated only when some significant change of plan occurs, or after the lapse of some reasonable period, such as three years.

The Future of Air-Cushion Craft

By L. D. CATHERS

From *Machine Design*, U.S.A., Vol. 32, No. 14, July 7, 1960, pp. 24–28, 7 illustrations.

While it is true that the first full-scale successful prototype of a practical craft supported on a cushion of air is the British "Hovercraft", it is also true that many small test or demonstration machines have been built on this principle. This article briefly discusses the various methods used to maintain the air cushion and, since the air-cushion craft seems to occupy a place somewhere between the aircraft and a hydrofoil boat, but is at the same time a true amphibian, some indications are given as to how the craft may eventually develop to fill a useful gap in the transportation spectrum.

RIDING on a pillar of air and exerting a pressure of no more than 0·1 to 0·5 psi on the surface it traverses, the air-cushion craft or ground-effect machine is a vehicle which operates in close proximity to the ground or water and which derives all or part of its lift from a cushion of pressurized air. The idea is undoubtedly an attractive one, but, although various firms have now entered the field with experimental craft, ferries, and even cars and trains operating on this principle, the question as to whether the air-cushion vehicle can ever become a practical and useful proposition still remains to be answered. The U.S. Navy, pursuing a research programme of its own, seem to think it can, though preliminary work on the principles of the air-cushion vehicle suggests that its brightest future lies on the sea, not on the land.

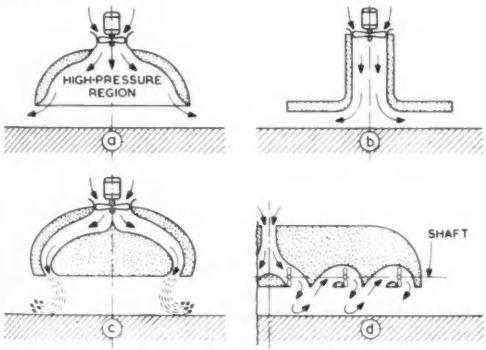


Fig. 1. Basic methods of maintaining the air cushion, showing (a) the plenum-chamber method, (b) the "Levapad", (c) the peripheral-jet method, and (d) the multiple-curtain method.

Many suggestions have been put forward for maintaining the air cushion or for propelling the craft with less power. Of the different methods of maintaining the air-cushion, most are variants of the four basic methods shown in Fig. 1. The plenum-chamber method is illustrated in Fig. 1a, in which air is pumped into a cavity beneath the craft and escapes into the atmosphere from the plenum periphery, the leakage area adjusting itself until the product of the plenum air pressure and its area equals the weight of the craft.

The method shown in Fig. 1b is the "Levapad", developed by the Ford Motor Company, and is more properly classified as an air-lubricated bearing. With this design, the very small ground clearances obtained result in high efficiency, but reduce the probability of its use over water.

The peripheral-jet method illustrated in Fig. 1c, sometimes called an air curtain, has received considerable analytical and experimental effort, its simplest form being typified by the well-known Saunders-Roe "Hovercraft", developed in England. In this design, all air from the nozzle is turned outwards, leaving parallel to the ground. The force required to turn this curtain of air accounts for the higher-than-ambient pressure under the vehicle.

Fig. 1d shows the multiple-curtain method. Also called the labyrinth seal, this refinement of the annular jet was proposed by Weiland, of Switzerland, pressure differential between the base of the craft and the atmosphere being accomplished in stages. Recirculation of the inlet air through the multiple fans reduces the amount of pumping power required.

Various suggestions have been made with a view to eliminating the air-sealing curtain along the sides of the craft. One of these is to provide around the periphery of the craft a flexible skirt which would be capable of yielding, if necessary. Another suggestion, under experimental investigation by the U.S. Navy and designated the "Hydro-Skimmer", is based on the use of an annular-jet design and longitudinal walls or "skegs" which extend downwards into the water, an air-curtain seal being required only at the bow and stern. Since fan-power requirements are proportional to the length of the air curtain, the required lift power is markedly reduced. However, the skegs cause considerable drag, necessitating an increase in power to overcome water friction; nevertheless, at the speeds at present envisaged for this design (50 to 70 knots), the reduction in lift power or hover power obtained more than makes up for this deficiency.

Naturally, as in the development of any new type of craft, numerous design and engineering problems still remain to be solved. For example, weight is a critical item. For operation over water, the structure must be much lighter than that commonly found in ships, and a balance must be struck between weight and the high cost associated with lightweight structures. Furthermore, the loads to which the structure is subjected are very difficult to ascertain and are, in fact, known only in a crude sense. Similarly, power-plant and air-pumping equipment must be adapted to operate in a salt-water atmosphere, and some applications may dictate the use of gas turbines, while others may be satisfactorily catered for by aircraft engines or high-speed lightweight diesel engines. For large ocean-going craft, a nuclear power plant may be the answer.

It should also be appreciated that very little is so far known of the response of an air-cushion craft in heavy seas, except in a very qualitative sense. Thus, if the craft proceeds very slowly, it will tend to follow the wave system; above a certain speed, however, it travels over the waves with little or no response. Resonant conditions undoubtedly exist which may make the machine unmanageable. In fact, research in many fields remains to be undertaken. It is not yet known, for instance, how

much water clearance is needed for an assumed sea condition. Furthermore, various control problems remain to be solved. Thus, as with any ship, control at forward speed is essential, and, depending on the design speed, the control surfaces may best be positioned either in the air or in the water. However, coupled with directional and yaw-stability problems arising from cross-winds, the problem of producing forward thrust and adequate control at both low and high speeds is by no means an easy one.

Noise and spray generation also present problems. High noise levels are associated with the delivery of large quantities of air, and various methods of lowering the noise level or of isolating personnel must be studied. Insofar as spray is concerned, experience indicates that spray tends to be left behind at speeds in excess of 30 knots; nevertheless, while hovering, the spray problem can be a very serious one.

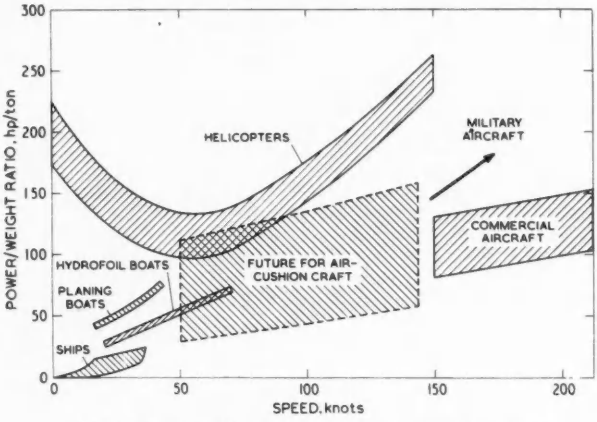


Fig. 2. Power/weight ratio as a function of speed for various types of transportation.

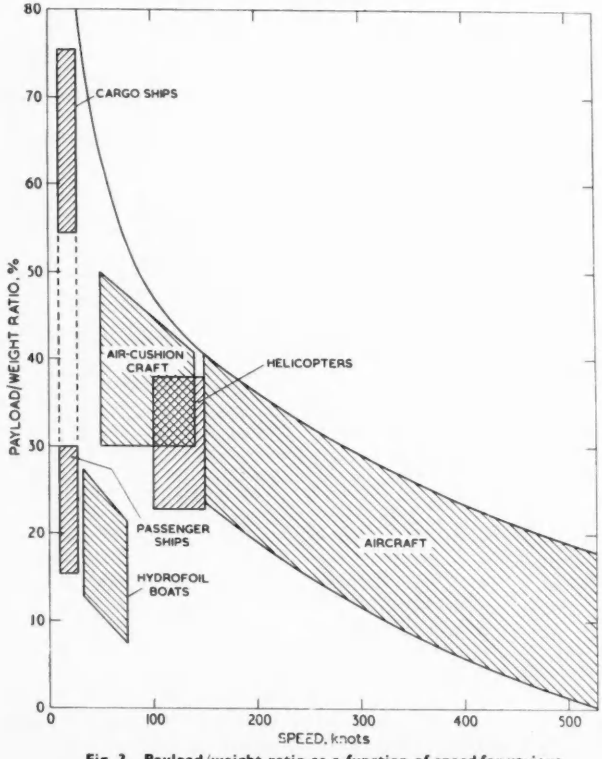


Fig. 3. Payload/weight ratio as a function of speed for various types of transportation.

The Future of Air-Cushion Craft

Many small test or demonstration machines, of from 10 to 30 ft in length, have been built on the air-cushion or ground-effect principle, and experience has tended to establish that surface clearances greater than about 10% of the length of the craft require large expenditures of power. With such a limited clearance, small machines are likely to be found practical in specialized applications only. Where, however, the terrain is essentially level, but with frequent transitions from land to water, or perhaps over mud and snow, the small air-cushion craft could undoubtedly prove invaluable and, since such a craft can travel with equal facility over any surface, it can be considered to be a true amphibian.

Perhaps the best application of the air-cushion craft will be as a large over-water vehicle. The ocean environment is often difficult to deal with, but, on the other hand, there are no hills, ditches, fences, or trees. Also, unlike the hydrofoil, the air-cushion vehicle becomes more efficient as its size and load-carrying capacity increase. In fact, with no theoretical size limit, air-cushion craft can be built perhaps 100 to 500 ft in length to achieve practical surface clearances for the severest wave conditions.

For a new form of transportation to gain acceptance, it must either do an old job better or do a new job. For example, there are only a limited number of ways to travel over water at a speed of 50 to 150 knots. The air-cushion ship seems to be particularly suitable for this speed regime.

It will undoubtedly receive serious competition from the hydrofoil in the lower speed range and from aircraft at higher speeds. If the air-cushion craft is to meet the challenge, its payload ratio should be between 30 and 50% of the overall weight. In large sizes, it will carry loads prohibitive for aircraft. Operating costs should be comparable with those of aircraft, but much less than those of helicopters. A vehicle of this type can perhaps best be described as a marriage between a ship and an aircraft, since it will have many of the characteristics of both.

To sum up, then it would appear that the advantages of the air-cushion craft are that it probably can be developed

(*Concluded on page 149*)

The Potentialities of the Free-Piston Engine

By A. BRAUN

From The *Engineering Journal*, Canada,
Vol. 43, No. 7, July 1960,
pp. 57–61, 7 illustrations.

A GREAT amount of literature has been published dealing with specific characteristics of free-piston engines. Many of the advantages, such as simplicity, good fuel economy, and multi-fuel characteristics, have been widely discussed. Furthermore, different possible arrangements have also been described in a number of publications. Thus, anybody particularly interested in this field can have a fair understanding of free-piston engines available and even of some of the engines in the test stage. These early designs, just as with most new developments, represent conservatively designed units to assure the introduction of reliable engines. These first designs can therefore be compared with, for example, early spark-ignition and compression-ignition engines. Modern free-piston engines, in other words, must be considered as in an early development stage, whereas the development stages of modern spark-ignition and compression-ignition engines are advanced designs working near the upper limits of their respective principles. It is therefore the purpose of this paper to point out the not yet utilized potentialities of the free-piston engine principle and to compare it with the potentialities remaining of further development or advancement possible with the principles of the three other types of internal combustion engines in current use, i.e., spark-ignition or petrol engines, compression-ignition or diesel engines, and gas turbines.

It can be shown that the basis on which the thermal efficiency η_{th} of each of these four types of internal combustion engine can be compared is

$$\eta_{th} = 1 - \frac{1}{r_v^{k-1}}$$

where r_v is the volumetric compression ratio and k is the isentropic exponent. By finding the maximum possible compression ratio r_v for each of the four engine types, a valuable indication of their respective actual efficiencies is available.

Spark-Ignition or Petrol Engines

Since spark-ignition engines depend on a fairly homogeneous air/fuel ratio throughout the combustion chamber, the mixture of air and fuel enters the cylinder during the intake period and a combustible mixture is compressed to a state just below its self-ignition point. The spark then ignites the mixture in one location and the flame propagates through the rest of the combustion chamber under controlled combustion conditions. In case the compression ratio is higher than that permitted by the self-ignition point of the fuel, uncontrolled combustion starts ahead of the spark ignition in many different locations of the combustion chamber and so-called knocking occurs.

A compression ratio r_v of 10 must be considered very close to the economical and practical limit; otherwise, fuel cost would become so high that the gain in efficiency would not balance, and an even greater specific output would not warrant the increase. The octane number and cost of fuel are therefore the limiting factors for the compression ratio in the spark-ignition engine.

Compressor-Ignition or Diesel Engines

In the compression-ignition engine, only the air is compressed during the compression stroke of the piston and to a state that is substantially above the self-ignition point of the fuel used. The fuel is then injected into the highly compressed air, and around each fuel particle combustion occurs independently of the overall air/fuel ratio in the combustion chamber, as long as each particle finds enough air for its proper reaction. Knocking in a diesel engine occurs when too much fuel has been accumulated in the combustion chamber before combustion starts. This happens if the chemical and physical ignition-delay period (i.e., the time that the fuel requires from the time of entering the combustion chamber until it starts actually burning) is too long. Since the ignition-delay period decreases with higher temperatures and pressures, i.e., with high compression ratios, it is very desirable in compression-ignition engines to have as high as possible compression ratios for good combustion behaviour.

With increasing compression ratios, however, the high pressures in the engine require heavy engine structures and, at compression ratios above 22, reach values that result in extremely high bearing pressures in the connecting rod and main bearings, besides an undesirably high loading of the pistons and liners due to high side thrust. Consequently, mechanical and structural requirements constitute the limitation for the compression ratio in the compression-ignition engine.

Gas Turbines

The gas turbine is a steady-flow type of engine, which means that the fuel is continuously burnt in the combustion chamber, whereas in the reciprocating type of engine the fuel is burnt intermittently. This means that, at the same maximum temperature in the cycle, the combustion chambers of reciprocating engines must withstand a thermal load only equivalent to the mean cycle temperature, whereas in gas turbines the combustion chambers must withstand thermal loads equivalent to the maximum cycle temperature. The maximum temperature is substantially higher than the mean temperature, and compression ratios in gas turbines must therefore be kept low. As a result, metallurgical or material requirements limit the use of high compression ratios in gas turbines to a value of 7.

Free-Piston Engines

As already indicated, spark-ignition engines require the air/fuel mixture to be compressed, so that the knock characteristics of the fuel limit the compression ratio to a value of 10, as suitable fuels become too costly above this value. In compression-ignition engines, the fuel imposes no limitations on compression ratio, which is, however, limited by the load on the bearings and pistons, so that, with a compression ratio of more than 22, diesel engines tend to become too heavy and their life too short. In the case of gas turbines, maximum temperatures in the combustion chamber and turbine impose a limit on compression ratio, so that, with compression ratios higher than 7, combustion-chamber and turbine-blade materials do not stand up.

In the free-piston engine, the compression-ignition

principle is compounded with the gas turbine in such a way that, in the compression-ignition part of the engine, gas is produced to feed the turbine, which produces the net power (and no more) of the compound power-plant. Because of this characteristic of the free-piston unit, it is usually called a free-piston gasifier.

Since, in the free-piston gasifier, the compression-ignition principle is applied to convert the fuel energy into work, it is insensitive to fuel and, from a fuel point of view, imposes no limit on compression ratio. Furthermore, the two pistons are not connected to any drive mechanism or mechanical power pick-up (except for auxiliary drives), but rather oscillate freely in an opposed reciprocating motion inwards and outwards. Except for losses, all the work done by the diesel or power parts of the pistons is transmitted to their directly connected compressor parts. Thus, bearings are eliminated and side thrust is negligible. In this manner, it is possible to utilize fully the compression-ignition principle, together with such extremely high compression ratios that they would be intolerable in conventional types of compression-ignition engine.

Similarly, the other part of the compound free-piston power-plant, i.e., the turbine, is employed in such a way that its positive characteristics, such as structural simplicity, low weight, superior torque characteristics, and the ability to expand the combustion gases to atmosphere, are fully utilized. The difficulties resulting from high entry temperatures, however, are eliminated, since the temperatures of the gases supplied by the gasifier and entering the turbine are far below those in a conventional gas turbine. The reason for this is that the free-piston turbine part has to provide only the net work of the compound power-plant, whereas, in the conventional gas turbine, the turbine wheel has to provide this net work in addition to the compressor work. The net work in the conventional gas turbine is only one-third of the total work to be supplied by the turbine, and the remaining two-thirds of the work done by the turbine has to be fed back to its own compressor. Since, in the free-piston compound power-plant, this compressor work is already done in the (intermittently working) gasifier, the enthalpy of the gases and their temperature for the same net horsepower are substantially lower than in the conventional gas turbine.

Present-day free-piston engines operate with volumetric compression ratios of from 40 to 60, but ratios of 80 and above are within the scope of relatively short-range development work and by no means represent the actual limits.

TABLE I: COMPRESSION RATIOS AND EFFICIENCIES OF INTERNAL COMBUSTION ENGINES

Type of Engine	Compression Ratio	Theoretical Thermal Efficiency	Actual Efficiency
Gas turbine	7 : 1	54·1%	22%
Spark-ignition	10 : 1	60·2%	28%
Compression-ignition	22 : 1	70·9%	36%
Free-piston: (actual)	40 : 1	77·2%	38%
(foreseeable)	80 : 1	82·7%	41%

For purposes of comparison, representative values of compression ratio for the four different types of internal combustion engine and the corresponding theoretical thermal and actual efficiencies are shown in Table I.

It should be appreciated that actual efficiencies are influenced by a number of variables other than compression ratio, such as fluid and mechanical friction losses, heat-transfer rate, combustion efficiency, etc., so that the percentage increase in theoretical thermal efficiency is not the same as that in actual efficiency, though the general trend is, with few exceptions, the same as that indicated by the theoretical thermal efficiency. It can also be seen that, to different degrees, this trend is in an upward direction, and it should be recalled that gas turbines and spark-ignition and compression-ignition engines are working on their upper limits after a comparatively long period of development and research effort, whereas the first free-piston gasifiers were installed only a few years ago.

Moreover, the increased efficiency of the free-piston principle is not achieved with a more complicated, but rather with a greatly simplified, engine, with a number of advantages over conventional types of internal combustion engines. Thus, the absence of crankshafts, connecting rods, bearings, camshafts, valve mechanisms, flywheels, etc., results in a structurally very simple engine, compared with compression-ignition and spark-ignition engines. In addition, because of the absence of any drive mechanism and because of the opposed reciprocating motion of the two piston assemblies, which are essentially the only moving parts in the engine, the free-piston gasifier is inherently balanced and, since there is no vibration, foundations can be substantially lighter and less costly. It should also be appreciated that, since there is no common crankshaft required for a multi-cylinder installation, there is no reason to build multi-cylinder units. On the contrary, it is advantageous to produce single-cylinder units which can be suitably coupled to power packages or independently installed in sections of the power-plant or vehicle for optimum weight distribution.

Even at their present stage of development, it can thus be seen that free-piston engines not only compare very well with, but are in many regards superior to, conventional power-plants. Nevertheless, specific fields in which they can be considerably improved are their power/weight ratio and their compactness. Also, despite their advantage in being able to operate on practically any fuel which the injection pump can handle, a considerable improvement in their fuel consumption still remains to be obtained. In this connection, it will be remembered that part of the air supplied by the compressor does not participate in the actual thermodynamic cycle. Since the power produced in the compression-ignition section of the gasifier has to be used up by the compressor parts, in order to achieve the necessart balance in this section, the overall air/fuel ratio decreases with increased compressor delivery pressure until it reaches a value that cannot be further reduced (the smoke limit of the engine). This critical compressor discharge pressure is about 170 psia and is equivalent to a volumetric compressor compression ratio of 6. The compressor compression ratios of the free-piston engines discussed are about 3, and the result of any increase over the present value will bring about higher overall efficiency and better fuel consumption, as well as lighter and more compact units. At the same time, however, it should be noted that the overall specific fuel consumption of present free-piston engines is about 0·365 lb/shp-hr, a value that compares very well with that of the best diesel engines, and that this can be achieved with a much cheaper fuel than a comparable diesel engine is capable of using.

(Concluded on page 117)

Dynamic Testing Machine for Large Diesel-Engine Bearings

By O. HOLFELDER

From *Technische Rundschau Sulzer*, Switzerland, Vol. 42, No. 1, 1960, pp. 37–44, 8 illustrations.

THE trend of diesel engines towards continuously increasing outputs by pressure-charging and higher running speeds has imposed considerably greater loads on bearings. It is therefore essential to maintain the service life of plain bearings at least at its present level and, if possible, to increase their life, despite the greater specific loads involved, by improvements in design, materials, and lubricating conditions.

As bearings are required to have a minimum service life of 10,000 hr, the testing of new bearing types in engines is obviously a tedious and costly procedure, and for this reason it is normally necessary to investigate their performance in bearing testing machines, instead of in the engine itself. Besides simulating the actual conditions of the engine, these machines make it possible to reduce the duration of testing by a suitable choice of parameters and particularly by operating the machine at increased loads.

Because bearing testing machines (various basic types of which exist) simulate true operating conditions correctly only to a limited extent, the results they yield as regards service life and permissible loading pressures are not directly applicable to the bearings fitted in engines. Their value, however, lies in the fact that they enable a preliminary selection to be made among various types of bearings, since in most cases the bearing type and the combination of shaft and bearing materials giving the best performance in the testing machine will also prove to be the most successful in the engine itself. Nevertheless, it must be appreciated that the true service life of a bearing can only be determined by actual engine tests.

The Sulzer Bearing Testing Machine

For basic research on bearing problems, the testing machines currently developed have small journal diameters, i.e., for test bearings up to a maximum of 70-mm diameter, and it is for this reason that the bearing testing machine developed in Switzerland by Sulzer provides the possibility of testing fairly large bearings, i.e., up to 200-mm diameter, and up to 400-mm diameter in certain cases, using an assembly which is similar to that existing in the engine itself, and providing impulsive and reversing loads.

The basic principle of the Sulzer machine, two of which have been in service for five years, is that the load pulses, varying from a maximum positive value to a negative load acting along the same axis, are generated by means of a hydraulic system. For the purpose of maintaining simple design features, variations in load are not exactly similar to those in the engine.

The main components of the bearing testing machine are shown schematically in Fig. 1 and in section in Fig. 2. As indicated in Fig. 1, the test shaft (8), driven by a variable-speed (100 to 1500 rpm) d.c. motor (10), rotates in two oversize main bearings (2), supported in a rigid cast-steel frame (15). The test bearing (1), located between the outer bearing housings, is coupled by means of a connecting rod (with a spherically designed lower end, so as to obtain edge pressures, if required) to a double-acting loading piston (3) of a hydraulic cylinder, the upper chamber of which is continuously connected to a pressure accumulator (4), supplied with oil by means of a high-pressure pump from a tank (16). The eccentric (7), rotating with the test shaft, acts on two valves (5) and (6) via a connecting rod and a double rocking-lever system. According to requirements, this action takes place either once per revolution of the test shaft or after every two revolutions. In the latter case, a 2 : 1 reduction gear is used ahead of the eccentric, forming the eccentric drive (7a), instead of drive (7).

When valve (5) is opened and valve (6) is closed, the hydraulic fluid from the accumulator acts on the larger lower surface of the hydraulic piston. With valve (5) closed and valve (6) open, the fluid flows out of the lower working cylinder and only the annular upper surface of the piston (3) is subjected to oil pressure. A spring-loaded relief-valve (9) permits adjustment to a suitable constant back-pressure relative to atmosphere and thus enables the load to be varied within wide limits, the instantaneous load varying during the revolution of the test shaft, as in an engine.

Particular attention has been paid to designing the control system so that load reversal can take place as rapidly as possible (i.e., with a high rate of pressure rise per unit of crank angle). This has been achieved by maintaining at a small value the dead volume in the lower cylinder space, with a large pressure accumulator (4) and ample valve cross-sections.

Fig. 3 shows the load variation, indicated by means of strain gauges on the connecting rod of the test bearing. At 650 rpm, the rate of change of the load, measured at this position, is 1000 kg per degree of crankshaft angle. For a test bearing of 145 mm diameter, with an L/D-ratio of 0·55, this represents a rate of change of loading pressure of about 9 kg/cm^2 per degree of crankshaft angle, corresponding approximately to actual engine conditions. In four-stroke engines, the ratio of the maximum forces acting in the upward and downward directions (this can be termed the "load ratio") is between 2 : 1 and 3 : 1. In the testing machine, the peak load directed upwards has been chosen as a multiple of that occurring in the engine during the working stroke, in order to shorten the testing periods, but, owing to strength considerations, because the connecting rod is provided with standard big-end bolts, the maximum load acting downwards has had to be limited. For the service life of a bearing, however, it is not so much the actual value of the load ratio that is decisive as the fact that load reversal may occur from the positive to the negative direction.

When the testing machine is used to simulate the bearing-load conditions of a two-stroke engine (instead of those of a four-stroke engine, with load reversal), the only change required is adjustment of the relief-valve (9), so that the back-pressure on the discharge side will be so high that the force on the test bearing will no longer change its direction, but will always act upwards

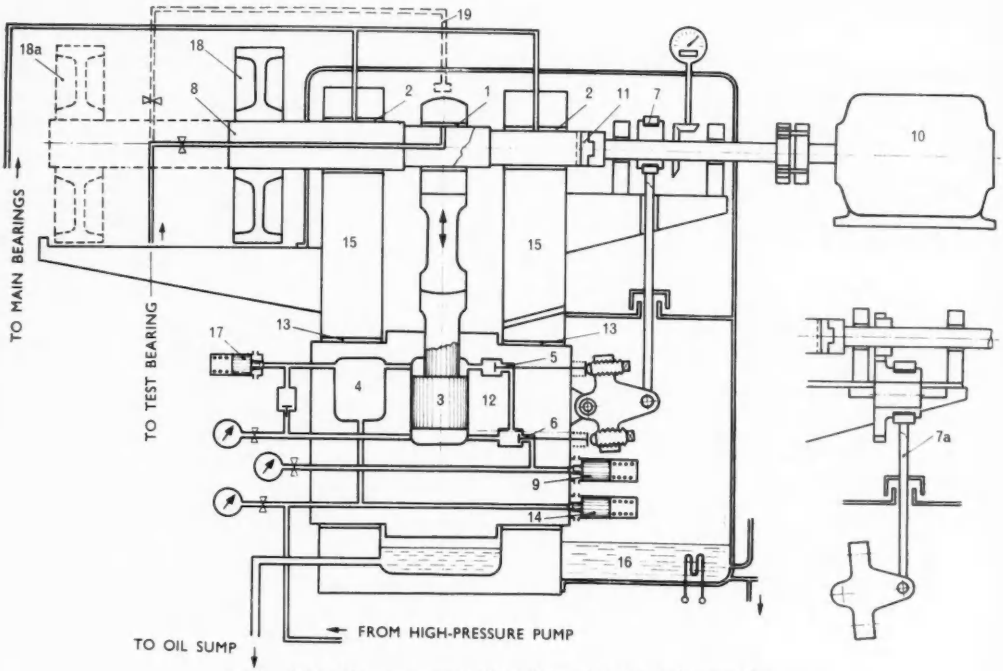


Fig. 1. Schematic arrangement of the Sulzer bearing testing machine.

while varying in magnitude during each loading cycle. Obviously, the machine can also exert a constant load, either upwards or downwards, either by keeping the lower regulating valve (6) constantly closed and the upper valve (5) constantly open, or vice versa.

The hydraulic loading portion of the machine, with all its actuating valves and instrumentation, is accommodated in the forged cylinder block (12) shown in Fig. 1. This block is supported in large bronze bearings (13) in the cast-steel frame in such a way that, when the test shaft (8) with its flywheel (18), used to ensure uniform rotation, is pulled out to the position (18a) shown dotted in Figs. 1 and 2, the connecting rod with the test bearing can be swung out laterally from the machine, as illustrated in the general view of the machine in Fig. 4. This makes it possible to inspect the bearing and the test shaft, and to take wear measurements, without dismantling the test bearing, i.e., without altering its clearance. An easily disconnectable Oldham coupling (11) is used between the test shaft and the drive.

The oil circuits are connected in such a way that the same lubricating oil is used for the test bearing and the supporting bearings, this oil being collected in a sump after issuing from the bearings between the main bearing supports. On the pressure side, however, the lubricating oil is supplied to the test bearing via a circuit (19), a separate circuit being used for the supporting bearings. The flow rate and temperature of the oil flowing through the test bearing can be adjusted according to requirements by means of valves and heater and cooler units, and continuous recordings are taken of flow rate and the total quantity of oil. The lubricating oil is supplied either through the hollow test shaft (for connecting-rod bearings) or from the outside through the bearing cap (for main bearings) to the bearing being tested. Depending on requirements, either pure lubricating oil or used engine oil is employed in this circuit. The hydraulic circuit for the loading piston (3) is entirely separate from the lubricating-oil circuits and is also provided with a cooler and a preheater arrangement. From the tank (16), the hydraulic fluid is supplied by means of a booster pump to a high-pressure multi-plunger piston pump, which generates pressures up to 700 atm, the load being varied by altering the pump delivery.

The machine is designed to operate for long periods without continuous supervision. When a failure occurs, the test is automatically stopped by relays and control gear which is sensitive, for instance, to falling oil pressure at the lubricated positions, to excessive increases in bearing clearance due to bearing wear, to decreases in peak loading pressure, to changes in running speed, and to increases in torque, possibly because of bearing seizure. The disturbance causing the shut-down is indicated at the control desk by means of signal lamps. All important data in connection with the test run are registered on a 12-channel recorder.

The load level is normally determined by measuring the peak pressure in the hydraulic system, by means of a pressure cell (17), this pressure being limited by a safety-valve (14). Proper functioning of the valves and rapid changes in load are checked at regular intervals by viewing on an oscilloscope the loading diagram provided by the strain-gauges on the connecting rod of the test bearing.

The temperature of the test bearing is indicated by a thermocouple arranged in a suitable plug, the thermocouple being held in position by spring pressure and giving the temperature of the bearing at a distance of 4 mm from the running surface. The arrangement is designed to permit rapid replacement of a test bearing

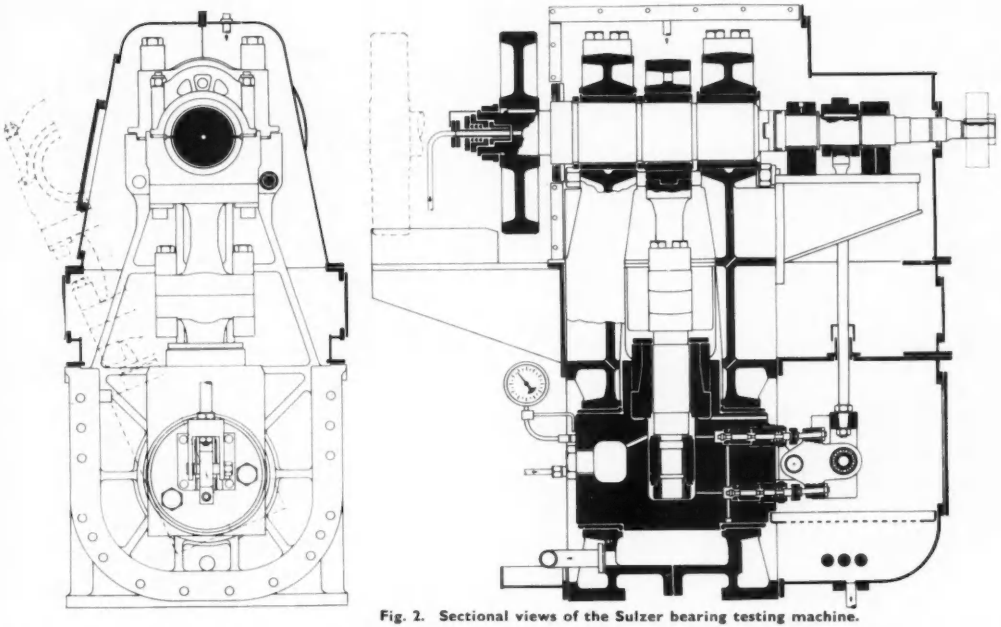


Fig. 2. Sectional views of the Sulzer bearing testing machine.

after each test. Additional temperature measurements are taken, when required, at other positions and also on the running surface.

Test Procedure

The two testing machines have so far run for more than 50,000 hours and have tested 90 different types of bearings. As bearing trouble occurs primarily in highly loaded four-stroke engines, the tests were mainly performed with bearings of engines of this type. As stated previously, the testing time was shortened by applying specific bearing loads which were from two to four times higher than those occurring in engines. The running speed of the test shaft (which is decisive for the formation of a hydrodynamic oil film) was either equal to the motor speed or was reduced to increase the severity of the test, with the same oil flow rate per unit time, so as to have larger Sommerfeld numbers.

The test programme was made as flexible as possible. In view of the inevitable amount of scatter associated with bearing tests, it was considered that at least three tests would be necessary to determine the effect of any design feature or operating condition. Thus, although the testing times were reduced by using increased loads, the overall periods of testing would be too long for practical industrial requirements if the programme were too widely spread. It was therefore decided not to include in the present programme any general tests of bearing design features, such as shape, elasticity, L/D ratio, position and shape of oil passages, etc., as these features had been explored elsewhere on smaller machines, and the results, broadly speaking, were applicable to bearings of different sizes. The determination of local lubricating pressures in the bearing, although also important, was deferred to a later stage.

The immediate programme was therefore to ensure the determination of suitable bearing materials and suitable combinations of crankshaft and bearing metals, to enable high-power engines to run at increased speeds, without requiring design changes or increased bearing surfaces.

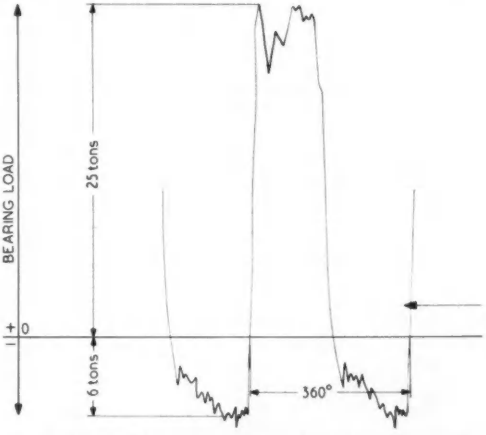


Fig. 3. Strain-gauge recording of bearing-load variations at a rate of 1000 kg per degree of crank angle and at a shaft speed of 650 rpm.

In the test procedure adopted, careful initial measurements of the test bearing were taken and, after a slow running-in period, the load was raised in steps of about 50 kg/cm² after each running period, which varied from 20 to 100 hr, the test bearing being swung out for inspection in each case. For bearing and shaft combinations similar to those normally used in engines, a fairly long run of 300 hr was first carried out under a load about 30% higher than that in the engine. For high-quality shaft and bearing combinations, a more severe load was

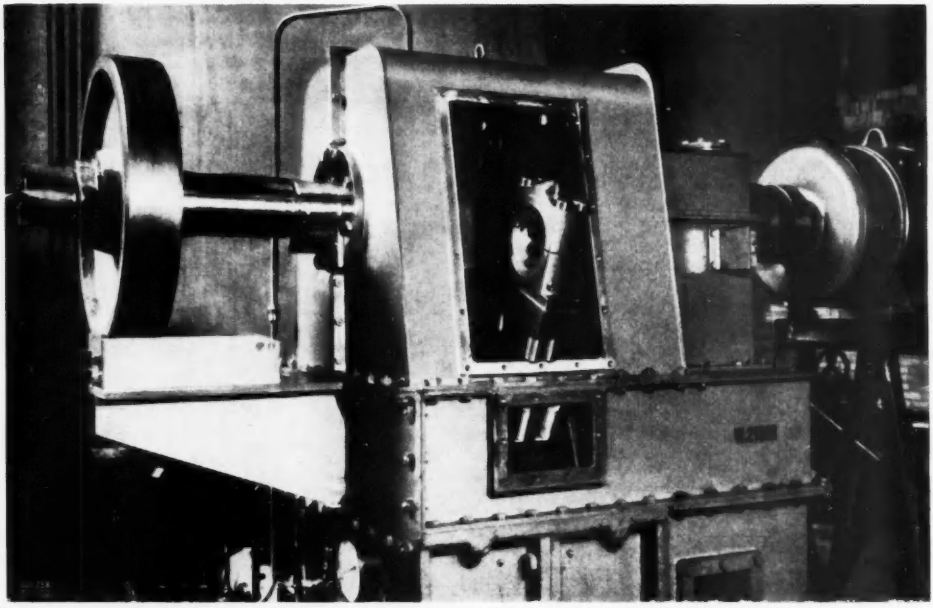


Fig. 4. General view of the Sulzer bearing testing machine, with a test bearing swung out for inspection.

applied. If the result was fully satisfactory, the load was raised gradually in runs of at least 100 hr, until destruction of the bearing occurred. As soon as damage occurred in the bearing surface, the load was kept constant in order to follow the development of the fatigue failure under unchanged operating conditions. As far as possible, oil flow and oil-inlet temperature were kept constant in all tests. A test was considered successful if the bearing was in perfect condition after being subjected to a multiple of the engine load for a period of 1000 hr, or after approximately 50×10^6 reversals. The test was then discontinued and it was considered that 70% of the mean value of the specific load, determined with several test bearings, would be allowable in engines under continuous operating conditions. This assessment might seem somewhat arbitrary, but its results were found to be in good agreement with comparative tests on similar bearings in an actual engine.

Initially, it was intended to adjust the load, oil-flow rate, temperature, and speed of the testing machines in such a way as to obtain a typical "crazed-pattern" type of failure with ordinary white-metal bearings after about 4×10^6 load reversals or 100 hr running time. These values of load and running time would then have served to some extent as a comparative basis for subsequent tests with other bearings. However, in view of the restricted time available, it was not possible to carry out these exploratory tests as far and as broadly as desired because, with the increased specific loads and reduced oil-flow rates, the bearings showed other types of damage, such as scoring, in addition to the crazing which, with an initially perfect bond between the steel and white metal, are a typical indication of bearing-metal fatigue. It is known that scoring is due to mixed lubrication conditions occurring under excessive loads, or to crushing of the bearing metal, owing to a combination of high bearing temperatures and high loading pressures. Consequently, tests of this type up to extreme operating conditions were discontinued, and the incremental loading method was employed.

Test Results

Conventional thick-walled white-metal bearings, statically or centrifugally cast, were first investigated. The white metal was anchored to the backing metal (bronze and steel) by the usual means, i.e., dovetailing, spiral grooves, or large circular grooves. Various precleaning treatments were employed to ensure a good bond with the backing material.

As the object of the tests was to assess the improvement attainable with various bearing metals, the bearings used were all of the same basic design, and the results were related to those of standard white-metal bearings which were arbitrarily assigned a permissible dynamic fatigue strength of 100%.

The tests were made with a big-end bearing arrangement of 145-mm diameter and a width of 83 mm, with the test shaft rotating at a constant angular velocity of 68 rad/sec. The clearances between shaft and bearing were between 0·06% and 0·10% of the shaft diameter. The operating conditions over the ranges of loads covered by the tests corresponded to Sommerfeld numbers extending from 0·5 to 10·0, but values were kept between 3 and 5 as far as possible. Unless otherwise specified, the shaft was an unalloyed steel of 50 kg/mm² U.T.S. with a Brinell hardness of 165 kg/mm². In large engines, the use of crankshafts with hardened running surfaces represents a considerable increase in manufacturing cost; consequently, preference was given to those bearing metals which could run well with "soft" crankshafts.

An improvement in test results was first obtained with bearings having a thin lead-bronze interlayer centrifugally cast between the steel shell and the thinner

outer layer of white metal (about 0·5 to 1·0 mm thick) also centrifugally cast. These bearings have a load-carrying capacity which is about 30% greater than that of the standard white-metal bearings, by virtue of the fact that the fatigue strength of all bearing metals is known to improve by reducing layer thickness.

Appreciation of this fact has led to the development of lead-bronze bearings with an electrolytically deposited running-in surface of a softer bearing metal, only 0·03 to 0·10 mm thick, and the tests showed their ability to withstand loads up to 70% higher than those for the standard white-metal bearings, without excessive wear of the shaft and with "soft" crankshaft surfaces. However, they require a higher manufacturing accuracy, since scraping of the thin running surface is not permissible.

It is further worth noting that, with both these "tri-metal" types of bearing, the regions of "crazed-pattern" failures are also considerably reduced in size. Consequently, these bearings can run longer than white-metal bearings after the first signs of cracking appear.

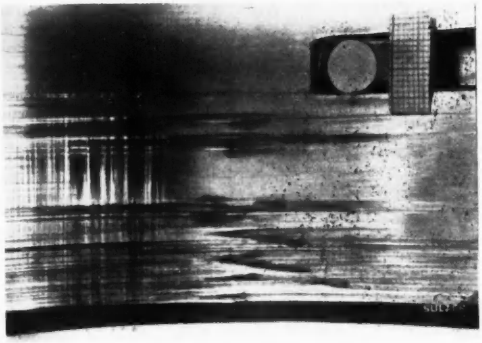


Fig. 5. Typical example of damage to an aluminium-alloy bearing surface after running in conjunction with a chromium-plated journal.

A further increase in load was found possible with light-metal bearings made with a backing shell and a rolled overlayer, about 1 to 2 mm in thickness, of aluminium containing approximately 6% tin. Previously, aluminium alloys were somewhat notorious for their poor running properties under critical conditions, with strength values of the same order as those for white metal. With the new alloy, it was only rarely possible to destroy the bearing by overloading. A conservative estimate based on the test results indicates that these bearings now permit loading capacity to be increased by 20%. Moreover, the high thermal conductivity of aluminium keeps these bearings fairly cool, even at high loads. Doubts about possible trouble due to differential stresses between the aluminium alloy and the steel housing at operating temperature were not substantiated, either on the testing machines or in actual engines. However, the higher thermal expansion makes it necessary to fit these bearings with a somewhat larger clearance (about 0·12 to 0·14% of the shaft diameter). Admittedly, the aluminium alloy, with its Brinell hardness of 40 to 50 at 20 C causes somewhat greater wear of a mild-steel shaft. This can be avoided, however, by electrolytically depositing a thin running-in layer.

To reduce the wear of mild-steel crankshafts, the pins and journals were hard-chromium-plated and then ground down to nominal size. With "tri-metal" types of bearings, this treatment gave good results and practically wear-free running. However, the chromium-plated shafts in conjunction with aluminium bearings showed frequent damage, even at low loads. Evidently, the extremely hard chromium layer and the hard aluminium surface do not produce good running conditions, aluminium-oxide particles being torn off the bearing surface, and the chromium layer being attacked and in turn causing damage to the bearing. This behaviour was repeatedly verified in the tests, despite great care with the oil supply. The damage occurred in the form of closely spaced striations extending around the shaft and the bearing, a typical example of this type of damage to a bearing being illustrated in Fig. 5. It has not as yet proved possible to eliminate this effect either by improvements in the chromium-plating and grinding of the test shaft or by deposition of overlayers on the aluminium-alloy bearings, so that, for the time being, their combination with a chromium-plated shaft is not acceptable. Tests with porous chromium plating have not yet been carried out.

A very hard surface, with excellent running qualities, has been obtained, however, with molybdenum sprayed on the running surfaces of the shaft, and this was also successful with the aluminium bearings, so that this problem can now be regarded as solved, without necessitating a thermal hardening or nitriding treatment, even for shafts of fairly large diameters.

The testing machines have also been used to assess various bearing configurations, and the advantages and disadvantages of a concentric annular lubricating groove in the bearing surface. In addition, tests are being performed on bearings with running surfaces made of epoxy resins. It is also interesting to note a series of tests which have been made with a white-metal bearing of 400-mm diameter for a special application, with a peak alternating load of only 85 kg/mm² but at surface speeds up to 20 m/sec. Besides investigating the running behaviour of this bearing, the tests also served to determine the frictional losses of the bearing under various loads. The measured results were compared with calculated values obtained in accordance with the data of Falz and Fränkel, and it was found that the measured values of frictional losses were significantly lower than the calculated values, owing to the particularly careful design of the oil passages in this large bearing.

The Potentialities of Free-Piston Engines

(*Concluded from page 112*)

Another way of increasing the efficiency of free-piston engines is to raise the compression ratio in the compression-ignition section, while another method of obtaining lighter and more compact units, apart from reaching the critical compressor discharge pressure mentioned above, is to supercharge the compressor sections of the gasifier. It should also be noted that the output of the free-piston power-plant increases directly with the speed of the pistons for a given engine design, and is inversely proportional to the square-root of the weight of the pistons.

In conclusion, it must be admitted that the above possibilities of improvement cannot be materialized immediately to their full extent, and further development and research work is necessary to reach the limits indicated, bearing in mind that, since conditions are considerably different from those in conventional engines, new approaches to the problems involved must be found.

The Present Status of Columbium Alloys

By L. P. JAHNKE, R. G. FRANK, and T. K. REDDEN

From *Metal Progress*, U.S.A.,
Vol. 77, No. 6, June 1960, pp. 69–74, and
Vol. 78, No. 1, July 1960, pp. 76–80, 10 illustrations.

DURING the past five years, considerable work has been devoted to searching out the metallurgical possibilities of columbium-base alloys by an increasing number of investigators, who are now aware that it is an attractive metal for many advanced uses and that it is, moreover, amenable to improvement by alloying. In fact, it would appear that no metal system has more vitality than that of columbium or holds more potential for assisting in performing many difficult requirements, particularly in the fields of nuclear energy and space exploration.

As its cost becomes reduced and as knowledge of the properties of the metal becomes more widespread, applications for columbium alloys will increase. In this connection, applications under consideration or being planned include the use of columbium alloys in jet-engine turbine and afterburner components, in ramjet nozzles, in nuclear power reactors, in space power generators, and in vehicles for glide re-entry.

The potential of the columbium-alloy system is best reflected by a number of key characteristics of the metal itself. Thus, its high melting point of 4470 F, while not the highest of all metals, is high enough to ensure that columbium alloys with a useful strength up to 3000 F can be developed. Also, columbium has good intrinsic ductility, and the relatively pure metal can be cold-rolled and has an impact transition temperature below — 100 F. It is also insensitive to interstitial impurities, unlike all the other refractory metals, except tantalum.

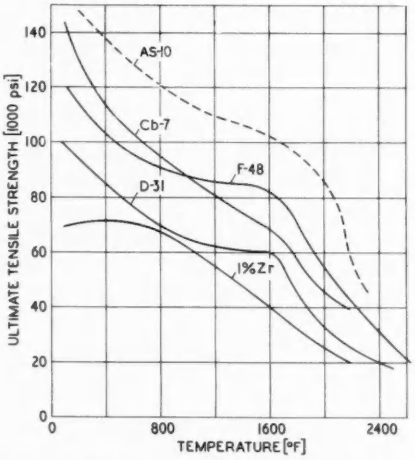


Fig. 1. Tensile strength of some columbium alloys.

Another key characteristic of columbium is its reasonable chemical inactivity, the metal being resistant to many acids and to liquid metals. Unfortunately, it is not very resistant to hot air (above 1200 F), though it is still one of the three most oxidation-resistant refractory metals, tungsten and tantalum being the other two. Still another useful property of columbium is its low capture cross-section for thermal neutrons. In this respect, it has the lowest value of all the refractory metals, making it of special importance in the nuclear field, since reactors must become hotter to be more efficient and compact. Finally, its specific gravity of 7·87, i.e., about the same as that of iron, is the lowest of the refractory metals, and this is of importance in air and space applications.

The interstitial purity of columbium, particularly with regard to the presence of carbon, oxygen, and nitrogen, is related to its form. Thus, the high level of interstitial elements present in columbium powder at first prohibited its use for the production of arc-cast alloys, while the use of vacuum-sintered solid rods and "pills" made homogeneous alloying exceedingly difficult. To indicate the progress made over the past five years, it may be mentioned that, in 1955, a fine-mesh columbium powder (325-mesh) contained 1000 ppm of carbon, 6000 ppm of oxygen, and 2000 ppm of nitrogen, while a vacuum-sintered rod contained 50 ppm of carbon, 250 ppm of oxygen, and 250 ppm of nitrogen, whereas to-day a 20-mesh powder contains 200 ppm of carbon, 500 ppm of oxygen, and 200 ppm of nitrogen. In addition, by using a technique of comminution of high-purity columbium ingots melted by an electron beam, it is now possible to produce relatively low interstitial values, e.g., 40 ppm of carbon, 250 ppm of oxygen, and 200 ppm of nitrogen for a 200-mesh powder.

Processing and Testing Problems

There is no general set of processing procedures for all columbium alloys because of their wide variation in properties. For unalloyed columbium and alloys with similar good ductility (and low strength), arc-cast ingots can be warm-forged (2000 to 2300 F) to billets and cold-rolled at room temperature to bar or sheet. The most serious problem here is the production of ingots for forging which are homogenous, fine-grained, and free from porosity. Another problem is careful conditioning of the sheet bar to eliminate areas which have dissolved oxygen during the warm-forging operation. If these areas are not removed, the finished sheet will contain isolated sections of material with little or no room-temperature ductility and will be subject to failure during forming and rolling. These problems can be controlled in competent production plants.

With high-strength columbium alloys, many problems associated with the processing of molybdenum are encountered, as well as others peculiar to columbium. Since columbium is generally more highly alloyed than molybdenum, it is more difficult to arc-cast homogeneous ingots. However, by using electrodes of blended powders and through proper control of arc power, melt-off rate, pressure, and stirring, ingots of excellent quality are being produced, containing elements which have either a high melting point (such as tungsten) or a high vapour pressure (such as aluminium).

Ingot breakdown of columbium alloys is much more difficult than with unalloyed metal, hot extrusion at

about 2800 F being the preferred method. Rolling high-strength alloys is also carried out at elevated temperatures. Laminations, 45-deg. cracking, and poor surface condition have caused problems, but by far the greatest difficulty has been the contamination of the surface from exposure to high-temperature air during the extrusion and rolling cycles. Rapid induction heating for extrusion helps to avoid this, but "in-process" coatings to prevent oxidation are a necessity for rolling thin, high-strength sheet, and several such coatings have been developed. A serious problem in processing refractory metals is the general lack of good high-temperature (4000 F) inert-atmosphere furnaces for rolling and annealing.

With regard to testing difficulties, early investigators of columbium alloys were constantly plagued by erratic test results. These were later attributed to residual oxygen in the testing atmosphere which dissolved in the specimens and strengthened them, obscuring the effect of carefully contrived variations in composition. As an example, a 10% Mo, 90% Cb alloy had a 100-hr strength at 2000 F of 16,000 psi, when tested in a good dynamic vacuum. When tested in tank argon, its strength was more than doubled.

It is necessary that high-temperature testing be done in a dynamic vacuum of at least 10^{-4} mm Hg to avoid spurious results, this being expecially true for long-time tests. Precautions may be necessary in hot-wall furnaces to avoid vacuum-plating of nickel and chromium on columbium from materials in the furnace wall.

Columbium Alloys of To-day

A number of columbium alloys have been produced, some on a commercial basis, by various laboratories working in this field, the most promising of these alloys being listed in Table I. It should, however, be appreciated that these are by no means the only known columbium alloys, but that they either hold the most promise for high-temperature use or best describe the various classes of alloys as a whole.

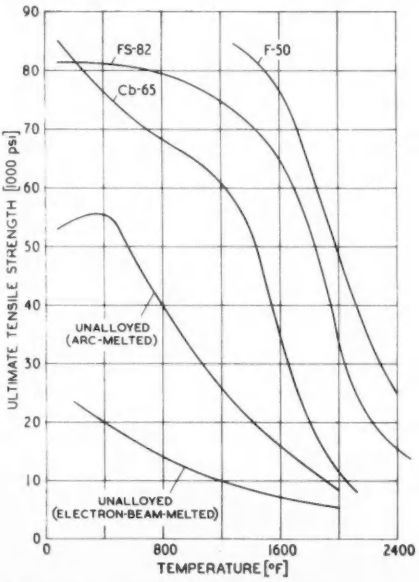


Fig. 2. Tensile strength of some columbium alloys, compared with those of unalloyed arc-melted columbium and electron-beam-melted columbium.

TABLE I: REPRESENTATIVE COLUMBIUM ALLOYS OF TO-DAY

Designation	Nominal Composition	Status
FS-82	33% Ta, 1% Zr	Commercial
1% Zr	0·75 to 1·04% Zr	Commercial
F-48	15% W, 5% Mo, 1% Zr	Pilot-production
F-50	15% W, 5% Mo, 1% Zr, 5% Ti	Pilot-production
D-31	10% Ti, 10% Mo	Pilot-production
Cb-7	28% W, 7% Ti	Laboratory
Cb-16	20% W, 10% Ti, 3% V	Laboratory
Cb-65	7% Ti, 0·8% Zr	Pilot-production
Cb-74	10% W, 5% Zr	Laboratory

Of the above, the FS-82 alloy is made by the Fansteel Metallurgical Corporation, the D-31 alloy by the DuPont Company, and the Cb-7, Cb-16, Cb-65, and Cb-74 alloys by the Union Carbide Metals Company. The F-48 and F-50 alloys, made by the General Electric Company, have been arc-melted in ingots of 4 to 6 in. diameter and converted to bar and sheet. The 1% Zr alloys have been evaluated by most firms working in this field and were originally discovered because of the occurrence of zirconium in columbium ore and its carry-over into the reduced metal.

The Strength of Columbium Alloys:—

Alloy-development studies conducted since 1955 have resulted in appreciable empirical knowledge of the effects of various alloying elements on columbium. With high strength as a goal, the following conclusions appear useful:—

(1) Zirconium can be present in unalloyed columbium in dilute quantities, and has been found to contribute significantly to strength.
(2) Titanium as low as 5 to 10% significantly improves oxidation resistance and, in most instances, helps workability, but weakens, rather than strengthens, columbium alloys.
(3) Tungsten and molybdenum are effective in strengthening the solid solution at high temperature. They also contribute moderately to oxidation resistance.
(4) Elements which confer the greatest oxidation resistance, such as chromium, aluminium, silicon, and titanium, have resulted in either brittle, unworkable, or weak alloys.
(5) Carbide and oxide dispersions in columbium alloys greatly improve high-temperature rupture and creep strength.

The strengthening mechanisms which have been found for columbium alloys are similar to those for the other high-temperature and refractory-metal alloys, i.e. solid-solution strengthening, work hardening, and dispersion hardening. All three mechanisms are combined in the strongest columbium alloys.

Since a majority of the proposed applications for columbium alloys requires service at elevated temperatures, their tensile and stress-rupture properties are of great interest. In this connection, Figs. 1 and 2 compare the tensile properties of some of the alloys listed in Table I. In addition, Fig. 2 shows the tensile strengths of unalloyed arc-melted and electron-beam-melted columbium.

The tensile properties shown in Figs. 1 and 2 were

determined on bar stock with tests conducted in a vacuum or in purified argon atmospheres. The properties reported are for material which has been warm- or cold-worked and stress-relieved, so that any strengthening due to strain hardening occurs below the recovery or recrystallization temperature. Of considerable interest would be a comparison of the properties of columbium alloys in sheet and bar form. However, at this stage of development such comparisons are lacking. Preliminary results on the F–48 alloy in sheet form have given tensile and rupture strengths at 2000° to 2200°F only 5 to 10% lower than those of bar stock.

The stronger columbium-base alloys compare favourably with alloys of other refractory metals, at least to 2500°F. Alloys Cb–16 and Cb–74 are not included in Figs. 1 and 2 because of insufficient data; however, tests at 2200°F, giving ultimate tensile strengths of 35,000 to 45,000 psi, indicate that they are among the stronger alloys. The tensile ductility of all the alloys in Table I is above 10% elongation at room temperature. Tensile transition temperature has not been measured, but is obviously below room temperature when the material is normally processed.

With regard to the future, it may be said that the design of improved columbium alloys will undoubtedly also combine all strengthening mechanisms and utilize the principles to better advantage, as more is learned about effects and interaction of alloy additions. For example, the addition of high-melting-point elements, such as tungsten and molybdenum, is most beneficial in increasing high-temperature strength, presumably because the higher-melting elements have less atomic mobility.

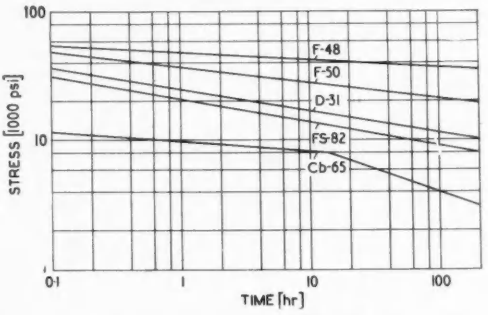


Fig. 3. Stress-rupture properties of some columbium alloys at 2000°F.

A greater use of carbon, and perhaps oxygen, as alloy additions to react with carbide and oxide formers, such as titanium and zirconium, may be expected. Such an approach, based on previous experience, will increase the recrystallization temperature and strengthen the alloy, as a result of the dispersion of carbides and oxides. The selection and balancing of carbide-forming elements to produce more stable dispersions of complex carbides offers a fruitful field for further work. In addition, the relatively unexplored field of true precipitation-hardening alloys, based on the formation of intermetallic compounds, must be studied.

The future for the development of columbium alloys is bright, particularly since the initial efforts have quickly produced alloys competitive with those based on molybdenum, which have been under study for many years. As some indication of future possibilities for columbium alloys, the ultimate tensile strength of a proprietary General Electric experimental alloy, designated AS–10, is included in Fig. 1.

Although not as yet fully understood, it has been found that substantial increases in strength are possible through heat treatment. Thus, work carried out by General Electric in 1957 on another columbium alloy (F–44, containing 15% Mo, 1% Zr) has shown that a 20% increase in 100-hr stress-rupture strength at 2000°F is possible by a high-temperature vacuum heat treatment, compared with conventional cold-worked material. A more precise knowledge of phase relations will permit a practical use of these effects of heat treatment.

The stress-rupture properties of some of the alloys listed in Table I are at present only sketchily known. Some comparisons from tests made in a vacuum at 2000°F are given in Fig. 3, while data available at 2200°F are given in Fig. 4. These alloys demonstrate a strength which makes them very promising candidates for high temperature service.

Modulus of Elasticity:—

The modulus of elasticity of columbium is the lowest of the refractory metals, and this was of early concern to structural designers. Though an excellent property for reducing thermal stresses (especially when teamed with columbium's low coefficient of thermal expansion), a low modulus is a handicap when designing on a basis of stiffness criteria. Early data showed a rapid decrease in modulus with increasing temperature. These data are not accurate, although the figures still crop up. The best information shows a gradual decrease from 17,700,000 psi at 70°F to 15,600,000 psi at 1650°F.

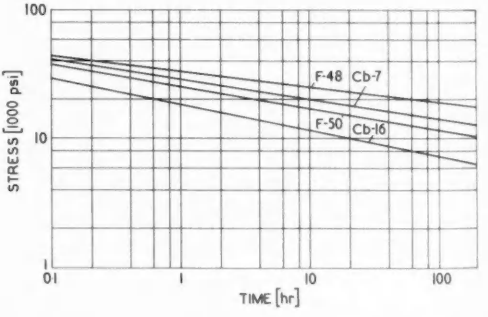


Fig. 4. Stress-rupture properties of some columbium alloys at 2200°F.

Alloying can increase the modulus of elasticity appreciably, especially if the high-modulus refractory metals (tungsten and molybdenum) are added. Tests on the F–48 alloy show a modulus of 25,000,000 psi at 70°F, and 21,000,000 psi at 1650°F, i.e., nearly a 50% increase over unalloyed columbium.

The increasing familiarity of air-frame designers with corrugated (or other stiffened) structures has made the modulus of elasticity of a material of secondary importance. However, to use such structures, the metal must be amenable to joining. Fortunately, the properties of columbium promise that most of its alloys will be weldable by modern techniques.

Ductile-Brittle Transition Temperature:—

As with all metals with a body-centred cubic structure, columbium and its alloys undergo a transition from ductile-to-brittle behaviour at a temperature which

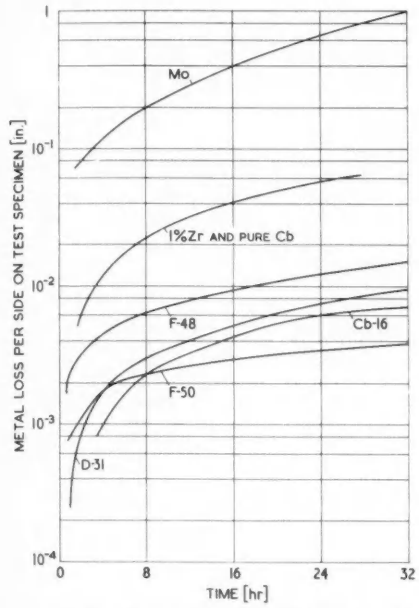


Fig. 5. Oxidation characteristics of pure columbium and some columbium alloys, compared with molybdenum, at 2000°F.

depends on the alloy composition and the test used. Pure columbium is very ductile, even at extremely low temperatures. Alloying to improve strength raises the transition temperature considerably.

Recrystallization Temperature:—

If strain-hardening is relied upon as a strengthening mechanism, a considerable reduction in strength occurs as a result of recrystallization. For example, molybdenum alloys lose up to 50% of their strength when recrystallized, and it was expected that columbium alloys would react similarly. However, data on the F–48 alloy show that almost complete recrystallization gives less than a 10% decrease in strength, indicating that this alloy obtains its strength primarily as a result of solid-solution formation and from dispersed particles. It is felt that other columbium alloys of this type will give similar results.

It is difficult to compare the recrystallization temperatures of columbium alloys because of significant effects of processing variables and because of the different tests by which they are determined. However, representative recrystallization temperatures for a 100% recrystallization to an equiaxed grain structure from a heavily cold-worked condition (70% to 90%) for a number of materials are 1800° to 2000°F for columbium, 2200°F for the 1% Zr alloy, for the D–31 alloy, and for the FS–82 alloy, 2500°F for the F–50 alloy and for the Cb–7 alloy, and 2600° to 3000°F for the F–48 alloy. It should be noted that, in the case of columbium metal and the F–48 alloy, the recrystallization temperature decreases with lower interstitial levels and the ranges noted above have, in fact, been obtained.

Oxidation Behaviour:—

Columbium oxide (Cb_2O_5) melts at about 2700°F, so that the existence of a molten or volatile oxide is not a problem for applications at present contemplated. However, a study of the oxidation behaviour of columbium-base alloys requires that consideration be given both to metal loss due to scaling and subsurface alloying with atmospheric gases. Fig. 5 shows the oxidation characteristics of some columbium alloys, compared with molybdenum, at 2000°F, while Fig. 6 provides data on the subsurface hardening of a number of columbium alloys.

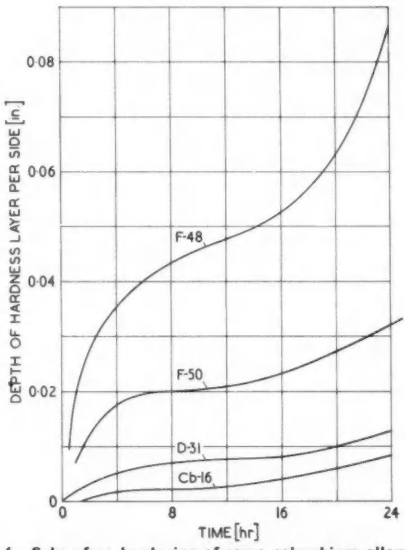


Fig. 6. Subsurface hardening of some columbium alloys as a result of contamination from heating in air at 2000°F.

The subsurface layer which forms during oxidation is brittle, cracking easily and thus acting as a sharp notch which may significantly reduce the load-carrying capacity of a columbium structure. The magnitude of this effect depends on the layer thickness and the toughness of the underlying uncontaminated metal. Although the rate of metal loss for columbium alloys due to oxidation is much lower (20 to 300 times less) than for molybdenum alloys, both scaling and subsurface hardening are too rapid for the alloys to be used at a high temperature without protective coatings, except for a very short time.

Surface-Contamination Effects:—

Because it is possible for failures to occur in coatings, it is of interest to study the effect of surface contamination (embrittlement) on the mechanical properties of columbium alloys. The only data available are for the F–48 alloy, but these describe the problem. Machined specimens were heated in air at 2000°F to produce varying levels of contamination and the data indicate that oxygen is mainly responsible for the hardening effect.

Electron micrographs show that diffusion occurs primarily along grain boundaries in this alloy. Other data have indicated that additions of reactive metals, such as titanium, cause the diffusion to occur more uniformly through the matrix of the grains, thus markedly decreasing the depth of the subsurface zone, presumably through scavenging effects.

Tensile tests on specimens heated for ½ hr and for 5 hr resulted in cleavage fractures below 1200°F in both instances. Above 1200°F, significant strengthening and gradually increasing ductility were observed. A 25 to

30% increase in high-temperature strength was also noted in stress-rupture tests. The creep rate at 2200°F was decreased ten times by "contaminating" 34% of the original cross-section.

Much more work must be done before these effects are adequately evaluated. There are obvious strength benefits from "oxygen-hardening" the surface, but the loss of ductility is serious and must be kept in mind when designing components for multiple missions.

Auto-Ignition:—

A phenomenon termed "auto-ignition" can occur with any metal when energy released by the oxidation reaction exceeds that lost by convection, conduction, and radiation. With columbium and its alloys, ignition occurs only at fairly high mass flow rates of air at a temperature determined to a great extent by the surface-to-volume ratio of the specimen. When the conditions are right, oxidation rates become self-accelerating, and catastrophic failure occurs. Thus, it has been necessary to study this phenomenon before considering certain applications for columbium and its alloys.

At mass flow rates of 1000 to 4000 lb of air per hr per sq ft of test area, the ignition temperature of columbium is about 2685°F. However, the ignition temperature for its alloys is lower, e.g., 2620°F for alloy F–48, and 2450°F for alloy F–50. The results of tests on unalloyed columbium in air with a mass flow rate of 4000 lb per hr per sq ft are shown in Fig. 7, in which the temperature was first stabilized in argon during the T_0-period.

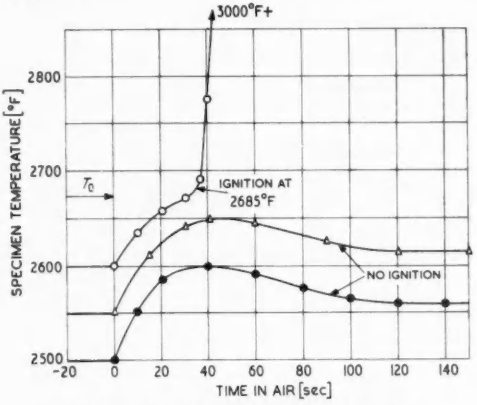


Fig. 7. Auto-ignition of unalloyed columbium.

Tests were also made on specimens of unalloyed columbium and F–48 alloy, on which protective coatings with intentional defects had been applied. Auto-ignition was not evident here, even at 2800° to 2850°F for 10 min. Thus, protective coatings decrease the possibility of auto-ignition, by effectively reducing the surface-to-volume ratio of the specimen.

Protective Coatings:—

The requirement for coatings on columbium alloys for structural applications at high temperstures is predicated on the need to prevent loss of ductility due to air "contamination" and to prevent auto-ignition. The reliability possible with columbium stems from the fact that small defects in the coating do not cause catastrophic failure, as is the case with molybdenum.

Coatings which have been developed for columbium include (a) sealed, flame-sprayed alumina, (b) hot-dipped, liquid-metal diffusion of aluminium or zinc, (c) solid-state or gas diffusion of silicon or chromium, (d) vapour deposition of silicon, chromium, or alumina, (e) cold-slurry dip of aluminium, and (f) electroplating of chromium.

The first three coatings are probably the most advanced and indicate potential excellence. For example, the sealed, flame-sprayed alumina coating will protect small columbium specimens for 30 min at 3000°F, or for well over 1000 hr at 2300°F. The main problems to-day are in applying the coating to large complex structures. Maintaining consistent quality is also of concern.

Weldability:—

Columbium, in contrast to molybdenum, has excellent weldability, this property resulting from its inherently good ductility, plus its high tolerance for interstitial oxygen and nitrogen. A wealth of knowledge has been accumulated on both the resistance and inert arc-fusion welding of unalloyed columbium, as well as for the weak but ductile alloys, such as the 1·0% Zr alloy, the Cb–65 alloy, and the FS–82 alloy. The joint efficiency of fusion welds, and the shear tensile properties of resistance-welded joints made in the 1% Zr and the FS–82 alloys are equivalent to properties obtained for stainless steel. In addition, it is possible to bend fusion-welded joints in these alloys through 180 deg., without failure.

Less is known of the welding behaviour of the high-strength and more complex alloys. It is believed that the solubility of oxygen, nitrogen, and carbon in alloys such as the F–48, F–50, Cb–7, Cb–16, and D–31 alloys, which have high concentrations of tungsten and/or molybdenum, is lower than in unalloyed columbium. As a result, it is expected that their weldability will be poorer. Resistance and fusion welding of the F–48 alloy is now being investigated. Methods for brazing columbium and its alloys are virtually non-existent, and it is generally felt that work in this area needs much more effort.

It is characteristic of new metal systems that, in the early years of alloy development, only those properties which specifically relate to the application in mind at the time are obtained. It is only when an alloy of some potential emerges from the laboratory that it is worth the cost and effort to determine complete design properties. Columbium has reached this stage of development within the past year and as a consequence only limited data are available on the physical properties of the alloys.

The Future of Columbium

It is predicted that, by between 1970 and 1975, columbium alloys will be employed for most applications in the range of temperatures between 1900° and 2600°F. They will also replace many present materials in nuclear power reactors and will find numerous applications in electronics. Their total use will amount to several million pounds of mill products per year, and alloy cost will drop to $15 to $20 per pound. Processing by arc-melting will gradually give way to more adaptable and economical powder-metallurgy methods, and most sheet rolling will be done in inert atmospheres. By 1975, the greatest progress in alloy development will have been made; thereafter, improvements will be in small increments, generally towards highly specialized applications.

Protection of Steam-Turbine Blades against Water-Drop Erosion by Spark-Hardening

By Yu. F. Kosyak and P. V. Savukov

From *Energomashinostroyeniye*, Russia,
No. 7, July 1960,
pp. 35–38, 6 illustrations.

Water-drop erosion of turbine blades is one of the most widespread troubles encountered in the last stages of steam turbines. Until recently, the most popular method of protecting the exposed turbine blades comprises brazing erosion shields, made of stellite or other hard alloys, to the outer regions of the last one or two rows of the moving blades. Other methods of protection include various diffusion and plating processes and the provision of special drainage belts.

The present trend towards the use of larger turbines, with correspondingly higher outputs and more advanced steam conditions, has once again focused attention on the problem of erosion of turbine blades, in view of their increased lengths and the higher peripheral speeds employed. To investigate some new method of combating the harmful effect of water drops on the performance and useful life of moving turbine blades, experiments have been carried out at a Russian electric power station on a 100-MW, 21-stage, double-flow steam turbine under actual operating conditions.

The experiments had three main objects, i.e., (1) to establish the magnitude and rate of erosion damage of the turbine blades with and without protective measures, (2) to incorporate a simple arrangement for the separation of moisture before the last stage of the turbine blades, and (3) to employ the method of spark-hardening in order to produce wear-resistant and erosion-resistant surfaces on the moving blades.

The steam turbine employed for the tests normally operates at a stop-valve pressure of 90 atm abs., a stop-valve temperature of 535 C, and a condenser pressure of 0·035 atm abs. The wetness of the steam before entering the last stage is 10·7%, and after leaving it 13·6%. The turbine blades are made of a chromium steel containing 0·09 to 0·15% carbon, 12·5 to 14·5% chromium, 0·5% manganese, 0·5% silicon, and 0·6% nickel. The blades have a maximum thickness of 4 mm, their length at the last stage being 740 mm. The maximum peripheral speed at the 21st stage is 447 m/sec, and at the 20th stage 350 m/sec.

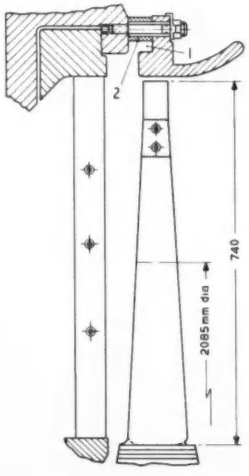


Fig. 1. Turbine blades of the last stage, showing the arrangement of the drainage belt.

During these experiments, the turbine was operated at lower steam temperatures and pressures, i.e., at 485 to 490 C and 80 atm abs., giving an output of 75 to 85 MW. After 1460 hr of operation, the turbine was stopped and the moving blades were examined and found to be substantially eroded, the greatest damage occurring above the zone of the lacing wires, with wear of the blade edge from the periphery extending over 40 mm. A further, more complete examination of the blades was carried out after 1820 hr of operation, when it was found that the inner half of the blades of the 21st stage did not suffer at all; at the outer half, erosion started with a zone covered by a matte deposit of iron oxides (as also were all the blades of the low-pressure stages), this being followed by a region of pitting erosion. The greatest damage again occurred at and above the zone of the lacing wires, the projecting part of the blades accommodating the holes for the lacing wires showing porosity, and the zone above the lacing wires being so eroded as to have a multitude of peaks and valleys of about 7 to 10 mm. Examination of the blades of the 20th stage showed that they had eroded to a considerably lesser degree. The fixed blades, however, suffered no damage whatever.

To effect moisture separation before the last stage, a special drainage system was employed, as shown in Fig. 1. In this arrangement, the moisture is flung off radially into a circular belt (1), the dimensions of which are determined by the width of a ring (2) fitted between the turbine casing and cover. While it is true that drainage of the steam in a radial direction causes a certain amount of power loss, this is more than offset by the considerable reduction in the retarding effect of the condensed water drops.

In order to assess the effect of the drainage system on the prevention of erosion, a drainage belt of this type was arranged before the last row of moving blades on the generator side, but was not fitted on the governor side. After 170 hr of operation, the blades were relatively undamaged on the generator side, while on the other side the same degree of erosion occurred as before. However, as the drainage belt alone does not afford sufficient protection over long periods of operation, further tests were therefore aimed at examining the suitability of spark-hardening, a relatively new process which permits a thin, hard, and erosion-resistant layer to be deposited on the surface of turbine blades, even if they have previously been damaged.

In these experiments, a standard electro-spark machine was employed, fitted with an electromagnetic vibrator for manual operation or with a special attachment for semi-automatic operation. The maximum output of the machine is 8 kW, the current being variable between 10 and 180 A. Depending on current conditions, the machine is capable of depositing coatings of from 0·1 to 1·5 mm in thickness at a rate of 1 to 10 cm^2/min. In the actual tests, the machine was operated only at the lower current ranges, in order to achieve uniform deposits with a smooth surface.

The electrode materials selected were (1) T15K6* (2) ferro-chromium, containing 73·2% chromium and 0·13% carbon, and (3) stellite, containing 61·7% cobalt, 25·5% chromium, 1·5% carbon, 0·75% silicon, 7·14% tungsten, and 0·85% iron. To compare the relative merits of these materials, the moving blades of the 21st stage of the turbine were divided into several groups, each of which was coated with a different alloy. The moving blades of the 20th stage were coated with the T15K6 material only.

The eroded sections of the blades were chipped, cleaned, and ground, and then spark-hardened. A current of 50 to 70 A and 25 V was used for most of the tests, except in the case of stellite, where the current was reduced to 30 to 40 A and 15 V in order to obtain surfaces of sufficiently good quality. It should be noted that the entire spark-hardening process was carried out with the blades in position and the turbine rotor supported by its own bearings.

After spark-hardening of the blades, the turbine was operated under analogous conditions for 190 hr with a drainage belt on the generator side, but not on the governor side. Subsequent examination of the blades of the 21st stage showed that the blades were free from erosion damage on the generator side, while on the other side they eroded to a certain extent, depending on the deposited material. The greatest damage was observed in blades spark-hardened with stellite, while the best results were achieved with blades spark-hardened with the T15K6 material; these blades were completely undamaged in that part of the flow where a drainage belt was used, and, even in the flow without a drainage belt, the contours of the blades remained smooth and only slight erosion was observed. In this connection, it is noteworthy that uncoated blades under similar conditions exhibited a wear of 3·8 mm from the periphery after 190 hr of service, corresponding to a rate of wear of 0·02 mm/hr.

From these tests, it is concluded that optimum protection of turbine blades can be provided by the combined use of a drainage belt and spark-hardening with the T15K6 material. In the final tests, therefore, a drainage belt was incorporated before the last stage of the blades in both flows, and the blades of the 21st and 20th stage were spark-hardened with the T15K6 material. The turbine was operated under these conditions for 6500 hr, after which the blades were found to be completely free from any signs of erosion. An important advantage of this method is its low cost and comparative simplicity, coupled with the fact that it can be carried out at the power station during overhauls or maintenance stoppages.

*A Russian sintered material containing 15% titanium carbide, 79% tungsten carbide, and 6% cobalt.

Chemical Protection from the Effects of Radiation

D. R. KALKWARF

From *Nucleonics*, U.S.A.,
Vol. 18, No. 5, May 1960,
pp. 76-81,130, 5 illustrations.

THE chemical protection of irradiated systems and the chemical promotion of radiation effects are outstanding accomplishments of the study of radiation chemistry and biology. By the addition of selected chemicals, it is reasonable to hope for a reduction in the hazardous effects on man of ionizing radiation, for the protection of exposed materials from damage, and for improved yields of radiation-induced reactions.

Although the absorption of ionizing radiation is not particularly dependent on chemical structure, the subsequent utilization of deposited energy varies considerably with absorber structure and environment, the basic problem being to manipulate these factors so as to facilitate some reactions and to retard others. Fortunately, the molecular events during irradiation are involved enough to be deflected at several different stages by added reagents.

Within a system, ionized and electronically excited structures decompose spontaneously, react chemically with their neighbours, and transfer energy to them. Subsequently, decomposition and reaction products react with other constituents until an ultimate composition is attained. It is possible to maintain or create desirable properties of the system by preventing decomposition of certain molecular components present initially or formed during irradiation. This is what is meant by "protection".

There are also systems in which it is possible to maintain desirable properties by regenerating components destroyed by radiation, and this is termed "restoration". It is often difficult to distinguish between protection and restoration and, indeed, a reagent may accomplish both. Chemical agents can also increase (promote) the apparent effects of irradiation.

On a microscopic scale, there are several mechanisms (some hypothetical and some confirmed) which can increase or decrease radiation effects. Thus, one method of protecting an ionized or electronically excited molecule from decomposition is by means of energy and charge transfer, i.e., by enabling the molecule to transfer its charge or excess energy to an added reagent, either by collision or by resonance transfer at a distance, the transfer being fast enough to compete with dissociation processes. Many laboratory experiments provide evidence of energy and charge transfer in irradiated systems. For example, a 32% reduction in the polymerization of irradiated acetylene is achieved by adding benzene vapour in a 1 : 3 mole ratio. The polymerization-inhibiting benzene has a lower ionization potential than acetylene. Conversely, additives with higher potentials promote polymerization. The formation of hydrogen from the decomposition of liquid cyclohexane is reduced 10% by 10^{-3}M benzene. Similarly, the addition of perdeuterobenzene protects benzene during gamma irradiation. Even in these simple systems, however, it is difficult to distinguish particular types of transfer processes and, in fact, several may be occurring simultaneously. There is also considerable evidence of energy and charge transfer in irradiated solids. Thus,

the main chains of polymethylmethacrylate are protected from scission by small amounts of various compounds dissolved in the polymer to form a solid solution.

Another method of affording protection is by scavenging. In this case, even though the molecules initially absorbing the radiation decompose, the system as a whole can be largely protected by inhibiting secondary reactions caused by decomposition products and other intermediates. Additives that react rapidly with these substances can sacrificially prevent their attack on other molecules in the system, the amount of protection depending on both the additive concentration and the ability to react with an intermediate on collision.

In general, free radicals are the most reactive class of decomposition products, and free-radical scavengers offer potent protection. The inherent ability of compounds to react with radicals varies widely. Thiourea, for example, has been found to react 2000 times as rapidly as the same concentration of urea. Oxygen, being a diradical, can become an important intermediate in promoting radiation damage. It reacts rapidly with other radicals to form peroxy radicals, which in turn attack compounds to form new free radicals and reactive peroxides. Other additives react selectively with molecular oxygen and peroxides; in fact, inhibitors usually present in commercial hydrogen peroxide limit its use in duplicating the hydrogen peroxide effects produced by irradiation of water.

Electrons are also potent reactants. Since positive ions are initially formed in excited states, neutralization of one of them with an electron produces an excited molecule which can decompose. It has been suggested, however, that, if a neutral additive can first capture the electron, it can in turn neutralize the positive ion with less chance of molecular decomposition.

An additive can also protect a compound by forming a molecular complex with it. The new structure may transfer energy and charge better and be less susceptible to attack by radicals and other decomposition products. Protection can also result from the formation of complexes across particularly sensitive bonds in the original compound. Various examples definitely suggest this type of protection. Thus, to take only two, the degradation of polyisobutylene is reduced almost 50% by copolymerization with 20% styrene, while the radiation resistance of the porphyrin ring is increased by complexing with vanadium and other metals.

Biological Protection

The prime goal of most research with chemical protective agents is to decrease the effects of ionizing radiation on living systems, particularly man. Most investigations are concerned with the protection of laboratory animals, usually mammals, from death caused by an acute total-body irradiation. Other biological organisms and methods of irradiation also provide valuable information, but extrapolation of the results to man is still a critical and uncertain step.

A useful protective agent in living systems must meet several criteria, one of the most imporant being that it be non-toxic at protective concentrations. It should also be easily introduced, become widely distributed, and remain intact for a long time before irradiation.

Despite differences in evaluation, a number of compounds stand out either because they exhibit a pronounced effect or because they suggest interesting protective mechanisms. Cysteine was one of the first compounds reported to protect living systems. The thiol and amine groups in this molecule have been the focus of much interest, and many other compounds containing both these groups have been examined. Among these, cysteamine and cystamine, 2-mercaptoethylguanidine and 3-mercaptopropylguanidine have been examined most intensively. The last two compounds are normally administered as the corresponding aminoalkylisothiuronium salts which rapidly undergo molecular rearrangement to the guanidine forms at the pH-value of the body.

Essentially, three mechanisms for the protection of these and other compounds are (1) the scavenging of free radicals, (2) the lowering of oxygen tension in tissue, and (3) the formation of complexes with sulphur-containing proteins. Unfortunately, however, these processes are difficult to distinguish in living organisms.

Known protective agents appear selective in their inhibition of radiation-induced effects in the body. The mercaptoalkylguanidines increase the mean longevity of animals, prevent induction of leukaemia, and protect against death, but they do not prevent nephrosclerosis, loss of fur colour, or cataract formation. Cysteamine protects animals from death following an acute radiation dose, but does not protect against genetic damage or sterility.

In most systems, protective agents are effective only if present during irradiation. It has been demonstrated, for example, that cysteamine is ineffective in protecting mice from radiation-induced death, even if it is given as quickly as 20 sec after a 25-sec radiation exposure. Treatment of human patients with cysteamine after X-ray therapy has been found to alleviate symptoms of radiation sickness, but this action was considered restorative, rather than protective. Recently, it has been observed, however, that, if the metabolic rate is low, protection can still be achieved shortly after irradiation. Thus, hibernating dormice and cooled bull spermatozoa have been irradiated and kept for several weeks, without evidence of radiation damage until warmed to room temperature. Moreover, this damage was prevented entirely by the addition of cysteine to either system immediately before warming. Similarly, the inhibition of cell division in irradiated dry bean seeds allowed to sprout in a nutrient solution has been prevented by the addition of either cysteine or cysteamine to this solution, the protective effect decreasing rapidly with time, becoming nil after 2 hr.

Observations of this type strongly suggest that some long-lived intermediates produced by radiation can be intercepted before they can continue the reaction chains in a living system. Studies *in vitro* have shown that free radicals formed from amino acids and other biologically important compounds during irradiation can be maintained for several weeks if they cannot collide rapidly with other molecules. Despite the potentialities for after-irradiation protection, however, there is no agreement about this effect in living systems.

Industrial Protection

Research on chemical agents to protect industrial materials or to increase radiation effects in them has lagged behind research on biological protection.

Some of the most active industrial investigations of chemical protection have been on lubricants for nuclear-powered equipment. The lubricating quality of mineral oils is protected by admixing aromatic compounds such as 1-methylnaphthalene or phenyl-*a*-naphthylamine.

Synthetic oils are protected by adding anti-oxidants and other compounds. The beneficial effect is not simply removal of dissolved oxygen. Thus, some conventional oxidation inhibitors actually accelerate radiation damage, while free-radical scavengers, not particularly known for their anti-oxidant activity, are protective.

Chemical incorporation of aromatic ring systems into oil is another way of protecting its properties, avoiding volatility problems. Alkyl-aromatic oils combine the high viscosity of alkyl chains with the energy-dissipative properties of aromatic rings. Polyphenyl ethers form another radiation-resistant class of oils which have the protective effect of aromatic rings.

Soaps, conventionally used in the gelation of greases, are particularly susceptible to radiation. Aromatic compounds, such as the terephthalamates, provide radiation-resistant gelling agents, and greases based on the Indanthrene dyestuffs are also useful in a radiation field.

An improvement in the properties of fluids such as reactor coolants should also be possible with chemical protective agents. As an example, the radiation resistance of *m*-terphenyl has been increased 30% by the addition of only 4% *p*-terphenyl.

Elastomers and Plastics

Many additives protect rubber during irradiation. While many of the usual anti-oxidants offer protection, the order of effectiveness is not closely related to anti-oxidant activity in rubber in the absence of radiation. Again, mechanisms other than oxygen scavenging are suggested. Compounds at molar concentrations equivalent to 2% hydroquinone have been found to inhibit up to 75% of the radiation cross-linking of rubber. In this case, protection was correlated with the ability to scavenge free radicals.

A variety of compounds noted for radical scavenging inhibits the radiation-induced cross-linking of polyethylene and polystyrene, while the cross-linking of butadiene is prevented by copolymerization with styrene. The inhibition of chain scission by chemical additives is important in industrial, as well as biological, applications.

Radionuclide labelling of the additive can be valuable for determining its action. For example, the apparent decrease in main-chain scissions of polymethylmethacrylate in the presence of naphthalene might be due either to the protective effect of naphthalene or to its use as a restorative link between broken chains. The absence of radioactivity in the irradiated main chains when C_{14}-labelled naphthalene is used eliminates the possibility that the action is restorative.

Sterilization

Chemical protection would also be profitable in the sterilization of food and medicinal products. Various additives have been used to modify undesirable effects resulting from protein decomposition in meat. The addition of acetic acid or tomato products proves especially beneficial in protecting beef from off-odour and off-flavour development. The decomposition of fat in irradiated meat is inhibited by the addition of citric acid or the deposition of various phenolic compounds.

Interesting examples of protective action are also observable in the radiation effects on food colour. The red pigment astaxanthin in shrimps is bound to a protein and is more resistant to bleaching than the same compound in salmon, in which it is dissolved in an unsaturated lipid. In strawberries, bleaching of the anthrocyanin pigment is prevented by adding ascorbic acid.

Protective agents may also prove valuable in the radiation sterilization of textiles. Wool, sterilized by radiation after treatment with fluorinated dinitrobenzenes or quinone, has been found to deteriorate much less than the untreated material.

Glass

Glass darkening has been ascribed to two processes, i.e., to the oxidation of cationic impurities and to the ejection of electrons into defect holes in the glass structure, both processes increasing light absorption. It has been known for some time that the addition of ceric oxide to glass minimizes darkening during exposure to ultraviolet light, and the same technique has been used to protect the transparency of irradiated glass. Presumably, the protective mechanism is scavenging of ejected electrons by ceric ions, which are reduced to colourless cerous ions.

Ion-Exchange Resins

Chemical protection of ion-exchange resins would be of considerable value during the separation of radioisotopes at concentrations resulting in radiation damage to the resin. Substituents on the polymer chain may be found to serve this purpose, since the resin structure apart from the ion-exchange sites appears quite important.

One sulphonated polystyrene resin loses from 15 to 35% of its exchange capacity per watt-hour of gamma radiation, while a sulphonated phenol formaldehyde resin loses only 1%. Protective agents such as *a*-chlorolose and cysteine, added to solutions in contact with sulphonated phenol formaldehyde resins, prevent an increase in the acidity index of the resin. It appears that hydroxyl radicals modify the properties of the resin by substitution and that the protective agents act as radical scavengers.

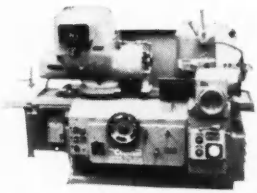
Synthesized Products

Radiation-induced synthesis reactions can also be profoundly changed by protective and promoting agents. The decomposition of carbon dioxide by ionizing radiation into carbon monoxide and oxygen appears to be a useful way of storing energy to be used through combustion. These products are not, however, formed in appreciable amounts when pure carbon dioxide gas is irradiated. Experimental investigation shows that carbon dioxide is not inherently radiation-resistant, but that its primary decomposition products rapidly recombine to give a net yield of zero. If nitrogen dioxide gas is added before irradiation, it reacts with some of these intermediates as they are formed, and the back reaction is impeded. Subsequent reactions then produce significant yields of carbon monoxide and oxygen and regenerate the nitrogen dioxide.

An important potential use of high-energy radiation is petroleum cracking, and protective agents may make possible the selective conservation of certain products. A step in this direction is the report that the addition of dibenzyl to irradiated *n*-heptane permits the production of other normal and isomerized hydrocarbons.

The key to managing the effects of ionizing radiation is in the knowledge of how various chemical structures can modify these effects. Some information on how chemicals protect is available, but exploration in the labyrinth of possible relations has only begun.

THE WINDOW ON THE WORLD OF MACHINE TOOLS



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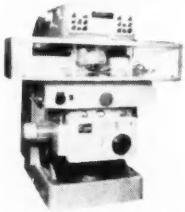

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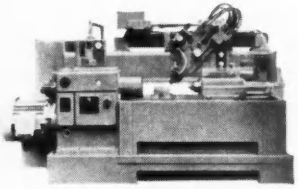

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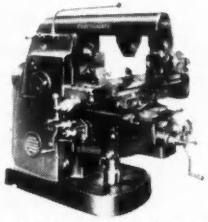

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Dielectric Heating - 3

Some further details of the uses to which dielectric heating can be put are given in this data sheet, being continued from data sheet No. 11.

The Woodworking Industry

A most important development in recent years in the woodworking industry has been the introduction of synthetic resin adhesives of the thermosetting type for the bonding of wooden components.

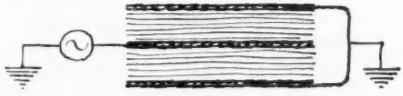
Setting of these resin adhesives proceeds at a rate largely determined by temperature. For instance, urea formaldehyde sets as follows :

TEMPERATURE	SETTING TIME
65°F	3 hours
80°F	1 hour
150°F	3 minutes
190°F	1 minute

The resultant bonded joint is equally satisfactory in each case. Most of the power supplied when dielectric heating is used is absorbed by the resin, the heat thus being concentrated where required.

Plywood

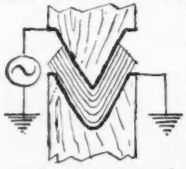
With dielectric heating consuming power only during the heating cycle, plywood can be produced with considerable savings in heating times and costs.



For example, in a press holding 100 3-ply ½″ thick assemblies, the resin glue is set in 20-30 minutes, depending upon the dryness of the wood.

Curved Laminated Sections

Curved laminated sections are being increasingly used in contemporary furniture, and with dielectric heating rapid production can be achieved using wooden shaping blocks in single daylight presses. An alternative method of providing heat by conduction from heated metal strips is much slower as the total section thickness rises above 0.05 inch.



Furniture Assembly

Because of the savings in glueing processes already instanced, dielectric heating is being extensively used in the furniture trade. It leads also to reductions in labour and floor space, with the elimination of assembly jigs. The heating equipment can be placed directly in the production line, cutting handling to a minimum.

Blockboard

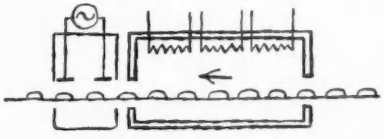
Blockboard, having large areas of glue line, provides an excellent use for dielectric heating, which gives considerable savings in time and labour.

Other Resin-bonded Products

Dielectric heating is also used in the manufacture of other resin-bonded or impregnated products such as grinding wheels, fabrics, felts, and similar products.

Foodstuffs

Increased use is being made of dielectric heating in many food processes; these include defreezing and melting, sterilisation and disinfestation, drying of breakfast



cereals, dog biscuits, etc., and similar applications. Some cooking processes, such as bread baking, are technically possible, but dielectric heating gives an 'unbrowned' product. In the biscuit trade, however, dielectric heating is combined with conventional baking to produce normal biscuits in ⅓ to ½ the usual baking time.

The examples given here cover only a part of the field open to dielectric heating.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone : TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available—"Induction and Dielectric Heating" is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity. Ask for a catalogue.

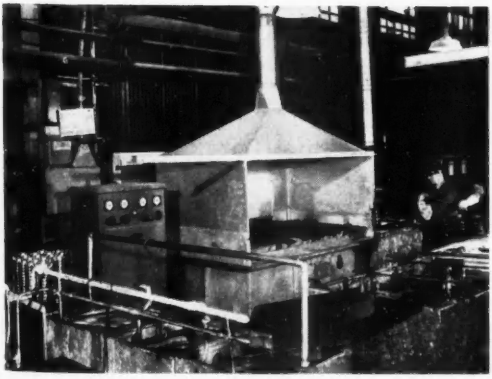
7568/2

British Industrial Developments

Electrically Heated Salt-Bath Furnaces

Offering all the accepted advantages of salt baths and producing work with a clean, scale-free finish, five new types of electrically heated furnaces are now being added to the range of oil- and gas-fired "Cassel" furnaces made by the General Chemicals Division of Imperial Chemical Industries Limited under exclusive licence from the Ajax Electric Company, of Philadelphia, Pa.

Of these five types of furnace, all of which are clean, silent, and simple to operate, three types, designated the "Cassel" Ajax S.R., S.S., and Q., are electrode-heated furnaces with rectangular pots. The salt in the pot is heated by current passing between electrodes immersed in the salt, and the life of the pot is therefore far longer than that of pots heated externally by gas or oil. The S.R. furnace is used for heat treatment with neutral salts in the temperature range between 700° and 1000° C, and the pot, which is made of interlocking refractory bricks, should last for from one to three years. The S.S. furnace is used for carburizing with various salts containing cyanide in the temperature range between 650° and 1000° C. The pot is made of mild-steel plate and should have a life of about one year. The type Q. furnace is used for the quenching and secondary hardening of high-speed steel in the temperature range between 500° and 700° C. The pot is made of mild-steel plate and should last up to two years.



The two remaining types of "Cassel" Ajax furnaces, designated the type T. and type T.I.Q., are intended for lower-temperature operation and are fitted with immersion heaters, the heat being produced by resistance elements immersed in the salt and suitably protected. The type T. furnace is used for tempering steel and for heat-treating aluminium alloys in the temperature range between 160° and 400° C, though special furnaces for temperatures up to 500° C are also available. The pot is made of mild steel and should last for from four to five years. The T.I.Q. furnace is used for quenching steel during austempering or martempering treatments, and agitation of the salt bath is so arranged that all parts being quenched are exposed to a uniform flow of molten salt, extracting heat rapidly and ensuring minimum distortion of the work. The pot is air-cooled externally to prevent the salt from rising in temperature. If parts have just been austenitized in a high-temperature salt bath, a separating chamber, in which the high-temperature salt is removed, is provided. A typical "Cassel" Ajax furnace, with a pot measuring 58 × 20 × 20 in. deep, used for austenitizing large and special sizes of ball- and roller-bearing races, is shown in the illustration.

Automatic Control of the Gauge of Cold Metal Strip

A new device for automatically controlling the gauge of cold metal strip has been developed by the English Electric Company Limited, of London, W.C.2, and experience shows that, besides giving a more uniform product, it also indirectly increases production by freeing the operator from constant supervision of the gauge. The device can be used for mills of any width, reversing or non-reversing, and can also be combined with the automatic slow-down equipment which English Electric have developed for slowing down a cold reversing mill at the ideal time for minimizing "thick-end" waste.

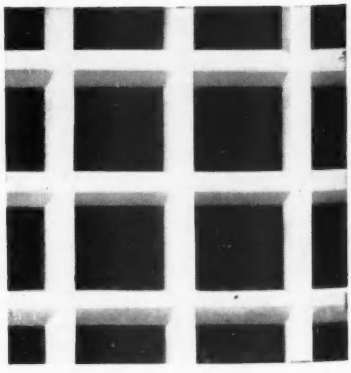
The system basically consists of a flying micrometer, a control panel, and a main control cubicle. The flying micrometer, mounted at the edge of the strip, measures the gauge of the rolled material. On a reversing mill, a micrometer is mounted on each side of the rolls, the intended gauge being registered on the front of the micrometer. The operator sets up his tolerances on the control panel, which can be conveniently mounted anywhere near the mill. Generally, this is done by a multi-position switch, tolerances of ¼, ½, 1, and 1½ thousandths of an inch being typical figures, though others can be provided. On automatic control, a continuous signal is transmitted to the control cubicle. When the error is greater than two-thirds of the tolerance setting, the screw-downs are operated and the distance between the rolls adjusted. For a reversing mill, the control cubicle contains three computing amplifiers, one for each of the two flying micrometers and one as a spare. Screw-down operation is initiated by high-speed contactors.

When the mill is rolling slowly, i.e., up to a critical speed, a sampling control system is used. After an error has been corrected, an electronic time delay ensures that the screw-downs do not operate again until the corrected gauge has passed through the flying micrometer, preventing the system from "hunting" for the correct gauge. When the speed is greater than the critical speed, the system changes to continuous control under the automatic operation of a relay in the control cubicle. The fastest correction possible is thus obtained with maximum stability. Incorrect setting of the flying micrometer, failure to apply the micrometer to the strip, a break in the strip, or running of the "thick end" through the flying micrometer would all show an artificial gauge error, and would cause incorrect and possibly dangerous operation if the automatic gauge control were allowed to respond. This is immediately prevented by an excess-error relay. Manual control is always available, whether automatic gauge control is selected or not.

special "thin-flash" type for grille moulding

Beetle D.M.C. is the material used for the grille of the Morphy-Richards Fan Heater because it offers high heat resistance and good appearance. The use of D.M.C. posed a flash-removal problem in relation to the many apertures, as the moulders, Crystalate (Mouldings) Ltd., specified a very thin flash line. Accordingly, B.I.P. Chemicals Ltd. developed a special type of material (D.M.C. L.1834) which, in combination with a tool made to close limits, ensures a consistently thin and easily removed flash.

Beetle D.M.C. combines heat resistance with strength, dimensional stability and excellent insulation properties. The development of a special type for a single application typifies the extent of B.I.P. services in relation to individual problems and requirements.



Heat resistance, dimensional stability, strength and electrical insulation properties are among the features making D.M.C. the ideal material for this grille. Moulding by Crystalate (Mouldings) Ltd., Tonbridge, Kent.

BEETLE*

Polyester dough moulding compound

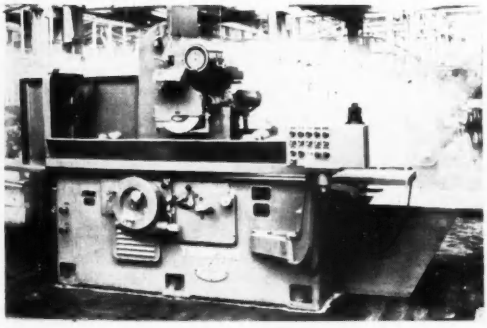
B.I.P. Chemicals Limited, Oldbury, Birmingham. Phone BROadwell 2061
London Office: Haymarket House, 28 Haymarket, S.W.1. Phone TRAfalgar 3121

"Truforming" Grinding Machines

Designed and developed by The Thompson Grinder Co., of Springfield, Ohio, Matrix Thompson "Truforming" grinding machines are now being manufactured under licence in the U.K. by the Coventry Gauge & Tool Co. Ltd. "Truforming" is an accurate and fast method of producing identical parts by transferring the shape or form of a preformed crushing roll first to the grinding wheel and then to the work, the crushing process producing a very free cutting wheel which gives an exceptionally high rate of stock removal. These machines, for which the Rockwell Machine Tool Co. Ltd., of London, N.W.2, are the sole selling agents in the U.K., are available in a range of sizes. The model illustrated, the BT8–12–36 machine, is one of the smallest in the range and has a table working surface of 12 × 36 in. The grinding wheel, 14 in. in diameter and 2 in. in width, is driven by a 5-hp, 1500-rpm motor, and the maximum height under the grinding wheel is 16 in.

In common with all British-built Matrix Thompson grinding machines, this model incorporates the patented and exclusive "Hydra-Cool" hydraulic system, developed to eliminate the effects of hydraulic-system heat, especially where work must be held to close tolerances during long production runs. By eliminating this heat at its source, this system prevents all distortion which might occur in the machine, particularly harmful distortion of the work-table. No external relief valves are used, and the supply of hydraulic oil is automatically regulated to suit requirements.

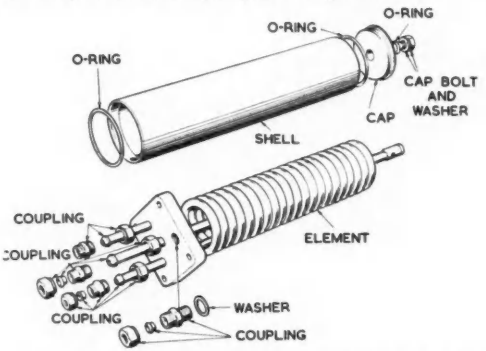
Infinitely variable table speeds, from 3 to 75 fpm, are provided, the table traversing on automatically lubricated Vee- and flat-ways, which are twice the length of the table work surface, thus providing adequate support, even at extreme traverses. The wheelhead cross-slide ways are flame-hardened and ground, and a patented anti-friction elevating nut ensures rapid and accurate positioning of the wheelhead. A micrometer back-up stop, graduated in divisions of 0·0001 in., is fitted to the elevating handwheel.



A slow-speed wheel-spindle drive unit is incorporated in the wheelhead for crush-forming the wheel. A crushing-roll fixture is fitted at each end of the table, one of these being equipped with a power drive. For initial crushing and for subsequent recrushing when production grinding, the wheel is fed down under timed automatic control into contact with the work roll in the right-hand fixture. For this operation the work roll idles. When the work roll loses its form after a number of crushing operations, the wheel is crushed by the master roll mounted at the other end of the table. The work roll is then reground with the grinding wheel running at normal speed and the work roll power-driven, this reprocessing being carried out without disturbing the work set-up. As both the master and work rolls are in precise alignment, the latter is restored to its original accuracy. Crushing rolls can be supplied to suit customer's requirements, and various auxiliary equipment is available, including automatic cycling feeds, circular form attachments, rolled thread die fixtures, etc.

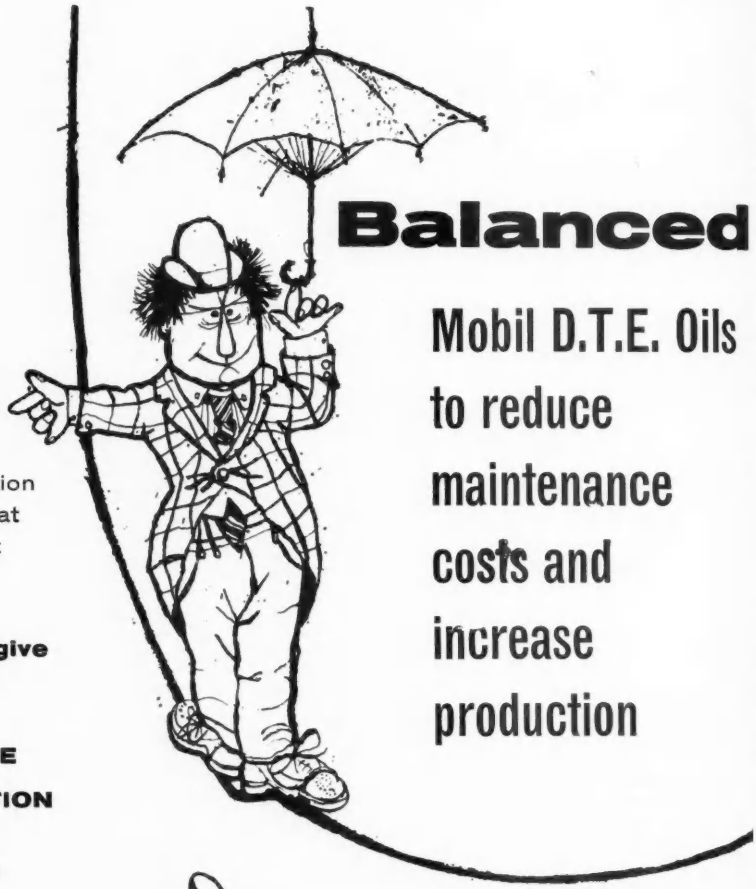
Compact Heat Exchanger

Although primarily developed to form an integral part of cooling systems for mechanical shaft seals, the "Heat Dissipater", announced by Crane Packing Ltd., of Slough, is also capable of application as a heat exchanger in its own right for many other purposes. Of particularly compact design and highly efficient in operation, it has a capacity of 10,000 BTU/hr. Two or more units can, however, be used either in series or in parallel when the rate of flow and the required temperature drop exceed the capacity of a single unit.



As shown in the accompanying exploded view, the unit basically comprises an element through which the liquid to be cooled is circulated, and a shell encasing the element, the coolant (normally water) circulating around the element. With the exception of the cadmium-plated mild-steel connections for the coolant, the standard unit is made entirely from stainless steel and is suitable for product pressures up to 2000 psi and coolant pressures up to 150 psi, with a maximum working temperature of the unit of 180° F. The shell is a seamless stainless-steel tube (pressure-tested to 200 psi), in which the stainless-steel cap is sealed by an O-ring. The element is a coil of seamless stainless-steel tube (pressure-tested to 3000 psi), silver-soldered into a stainless-steel end-plate. The product does not come into contact with the silver solder. The recommended flow rates for both product and coolant are from 20 to 120 gph.

By virtue of its construction, the unit, which has an overall length of 15 in. and a shell diameter of $3\frac{3}{16}$ in., is proof against attack from most corrosive liquids or gases passed through it. Furthermore, it has a considerable degree of flexibility in the method of mounting in relation to the particular equipment with which it is to be used. Normally, the unit is installed with the pipe connections upwards, as trapped air will then flow automatically to the open end of the pipe. It will, however, also operate satisfactorily in the inverted position, or within 10 deg. of the horizontal, provided that all airlocks are eliminated before starting up.



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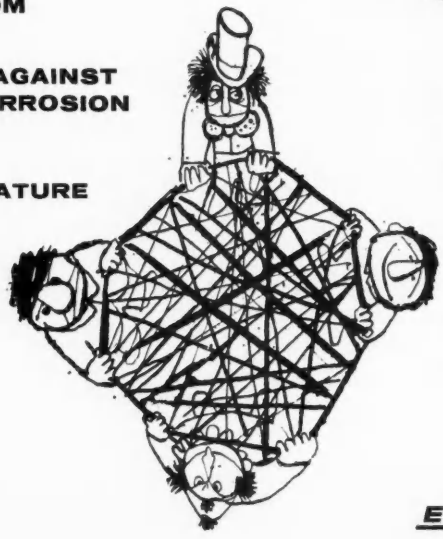

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Our representative will give you the facts — the facts about the performance of Mobil D.T.E. Oils in comparison tests with other well-known hydraulic and circulating oils. Ask the man from Mobil to call and explain how Mobil D.T.E. Oils can reduce maintenance costs and increase production

Mobil

ECONOMY SERVICE

High-Speed Oxyacetylene Cutting Nozzles

Stated to provide faster machine cutting speeds than any existing models, the latest addition to the range of "Saffire" equipment produced by British Oxygen Gases, Ltd., of London, S.W.1, is a series of high-speed oxyacetylene nozzles which can cut plates of 7 in. thickness at a speed of 45 fph or 1-in. plates at 100 fph. For this reason, it is claimed that the use of these nozzles will lower the production costs of machine cutting and will reduce the time spent on finishing and machine work.

The new nozzles, which are of one-piece construction and which, apart from the conical seating surface, are chromium-plated, are available in four sizes, i.e., with throat-passage diameters of 0·045, 0·050, 0·060, and 0·073 in. respectively. The cutting orifices, which are machined to very exacting limits, are of convergent-divergent form, permitting the cutting-oxygen supply to expand to atmospheric pressure within the nozzle. The cutting oxygen then leaves the nozzle at a high speed in a parallel stream, resulting in an exceptionally high linear cutting speed.

P.T.F.E.-Coated Glass Fabrics and Yarns

A completely new range of P.T.F.E.-coated fabrics and yarns is now being produced by Fothergill & Harvey Ltd., of Manchester 2. Known as "Tygaflor", the range embraces two types of coated fabric, i.e., types *A* and *L*, and coated yarns used for the braided surround of wires and cables, as well as an additional range of yarns for use as sewing threads on heat- and chemical-resistant fabrics.

"Tygaflor" coated fabrics are made by applying a smooth, uniform, and continuous coating of polytetrafluorethylene to woven glass fabrics, which are then slit into tapes of varying widths (¼ to 36 in.), or left in sheet form, depending on their ultimate application. The Type *A* fabric is used in electrical applications as an insulant and elsewhere for non-stick surfaces on heat-sealing machines, laminating platens, chutes, hoppers, etc., and also as a gasket material and for lining low-friction, non-lubricated bearings. The Type *L* fabric is similar to Type *A*, but has been specially treated to increase tear resistance and flexibility. As such, its primary application is in conveyor belting.

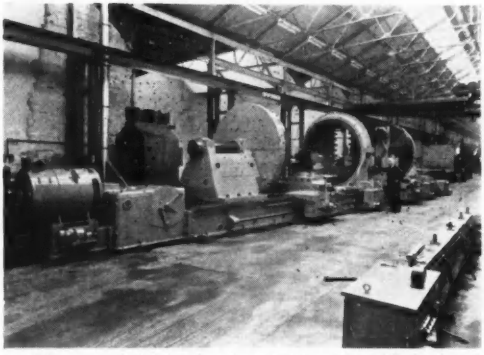
The excellent physical and chemical properties of glass and P.T.F.E. are combined in these new materials. Thus, "Tygaflor" has a low dielectric constant of 2·6 in combination with a high dielectric strength, enabling it to withstand up to 700 V per mil short-time, while absolute surface arc-resistance is another valuable electrical property. In addition, it is completely inert to nearly all chemicals, acids, solvents, and fuels, and is capable of withstanding temperatures between −100 and +250°C. Furthermore, it has very low moisture absorption, is completely weather-resistant and fungus-proof, and has a particularly high tensile strength, as well as high abrasion resistance, colour-fastness, and a marked ability to resist adhesion.

It is this property of resistance to adhesion that makes "Tygaflor", as exemplified by the Type *L* fabric, particularly useful in cases where it is required to transport sticky, resinous, hot, or moist materials, without the need for anti-blocking or release agents. Belts made from this material are dimensionally stable, can easily be spliced in various ways, and are available in three nominal thicknesses, i.e., 0·005, 0·006, and 0·010 in., with respective average breaking strengths of 110, 110, and 200 lb per inch width and safe working stresses of 5, 5, and 10 lb per inch width. The Type *A* fabric is available in a similar range of thicknesses and strengths, and also with a nominal thickness of 0·003 in., with an average breaking strength of 55 lb per inch width, providing very fast heat transfer for heat sealing.

Heavy-Duty Lathe for Turning Crankshafts

A 44-in. centre, heavy-duty lathe, suitable for machining large crankshafts between centres and also for offsetting them for the pinning operation, has just been completed by Henry Broadbent, Ltd., of Sowerby Bridge, to the order of Rotherham Forge & Rolling Mills Ltd., of Rotherham, Yorks.

The lathe has right-hand and left-hand headstocks, and also a central head, which drives and supports the work near the cutting position. The left-hand head is fixed and the right-hand head movable, the left-hand head having a fixed shoot and the right-hand head adjustable by means of a handwheel, with positive locking. The drive to the faceplate is by single helical reduction gears, and the pinion on the centre driving shaft has capped bearings, enabling the heads to be removed from the bed without withdrawing the centre shaft. The faceplates, which are 87 in. in diameter, are bolted to a solid flange on the spindle and are provided with tee-slots and an adjustable work-holder, which can be offset for pinning. In addition, each faceplate has four screws incorporated for taking independently adjustable chuck jaws. With these fitted in place of the work drivers, it is possible to use either headstock as a large facing lathe, in which case an interchangeable compound tool-post is fitted in place of the lighthouse tool-post.



The central driving head, which is adjustable by hand or rapid power traverse along the bed, has a hollow sleeve with a central totally enclosed spur-gear drive, the sleeve carrying a cast-steel work-holder for pinning purposes. All three heads are driven by a centre shaft, 6½ in. in diameter and approximately 40 ft in length, forged and turned in one piece. Provision has been made for removal of the shaft without having to withdraw from the end of the machine. The centre shaft is driven by a three-speed gearbox, situated at the extreme left-hand end of the bed. This gearbox, in conjunction

This is the equipment for the small drawing office

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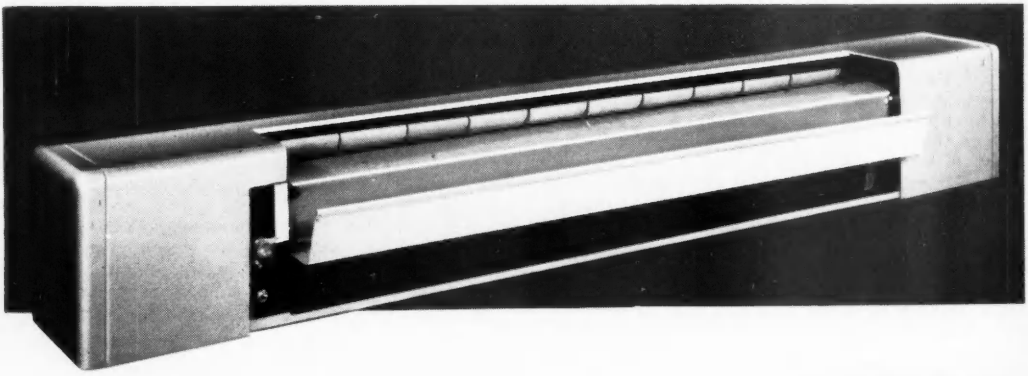

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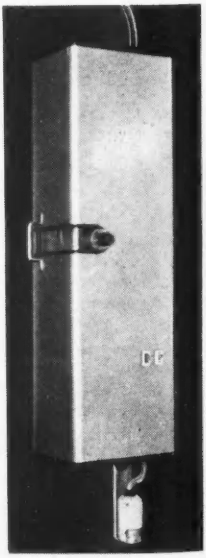

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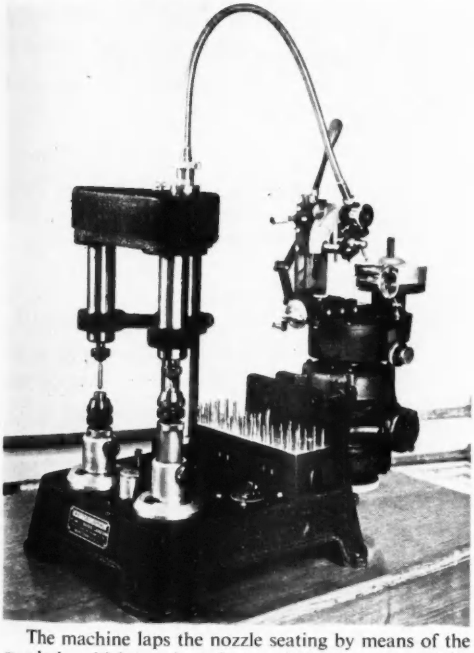
Machine for Lapping Diesel Injector Nozzles

The difficulties of reconditioning quickly and accurately the seatings of diesel injector nozzles have been overcome by a new machine, now being manufactured exclusively by Diesel Injection Ltd., of Ruddington, Notts., and originally developed and patented by the Lanzoni Company, of Mantova, Italy. Compact and simple in design, the machine, designated the "Lanzoni", is built for bench-mounting and is powered by a multi-voltage electric motor of 0·25 hp. This two-mandrel machine can lap and recondition diesel injector nozzles and also incorporates a high-precision rectifier for the conical needle seatings, normal manual or mechanized correction being entirely eliminated.



The machine laps the nozzle seating by means of the mandrels, which terminate in a conical lapper of specially treated cast iron. The axial hole of the injector nozzle is used as a guide for the mandrel. The conical seating needle can also be super-finished at the exact angle recommended by the nozzle manufacturer by a micro-polished lapping grinder located in the rectifier. A wide range of mandrel sizes ensures that a lapping mandrel is available for each individual injector nozzle being treated and, since there are two mandrels working simultaneously, it is possible to carry out operations very rapidly, on two nozzles at the same time, if necessary.

Located at the rear of the machine are two coaxial grinding wheels provided for the successive operations of grinding the cast-iron cones of the lapping mandrels and the grinding and consequent high finish of the needle cones, this latter operation being accomplished without any need to remove the needle. For retruing these two wheels quickly, a diamond in a bracket is fitted. A roller with a flexible drive rotates the needle, the carrier being adjustable to permit grinding at angles varying from 57 to 62 deg. The operations of injector-nozzle lapping and of reconditioning the nozzle seating can be concluded in a matter of minutes.

Television Relay Cables

To meet increasingly stringent specifications, particularly with regard to radiation, rejection of extraneous interference, and the minimizing of conductor and dielectric losses, in connection with the distribution of television programmes in modern V.H.F. relay systems, two new television relay cables, i.e., single-screened cables and double-screened cables, have been developed by Aerialite Ltd., of Stalybridge, Cheshire. It is stated that these two types of cable provide significant improvements in the reduction of direct radiation and the transfer of unwanted signals along the outer surface of the cable, but are robust and flexible enough to withstand field installation and service conditions. Furthermore, they are available in a range of conductor sizes up to 0·104-in. diameter, have excellent high-frequency characteristics, and, being of small size, are unobtrusive.

The single-screened relay cable incorporates the well-known patented "Aeraxial" polythene insulation, providing an attenuation characteristic which is lower than that obtainable in any other form of continuously extruded semi-airspaced coaxial cable. The primary screen on this insulation consists of a longitudinally folded copper tape with overlapping edges, covered by a copper-wire braid applied at the same time in such a way that it locks the edges of the tape and provides mechanical flexibility. The copper tape and braid are both covered by an electrically conductive thermoplastic sheath, which has a much higher specific resistance than the underlying metal and which functions as a surface barrier to the longitudinal transfer of radiation along the outer surface of the copper tape and braid. The conductor layer is protected by a substantial polyvinyl chloride sheath, resulting in a cable which is light, flexible, and tough, and with radiation characteristics similar to those of a conventional double-braided television relay cable, but with a considerable reduction in level in the immediate vicinity of amplifier and repeater equipment.

The double-screened version of the cable has an inner screen of close-mesh copper braid applied to an "Aeraxial"-insulated conductor and separated by an insulating intersheath from the secondary screen, which comprises a copper tape, longitudinally folded and overlapped and provided with an anchoring overlying braid, as in the single-screened cable. A conductive thermoplastic sheath and a protective outer sheath are provided, the radiation characteristics of the double-screened cable being even better than those of the single-screened version. The other electrical characteristics of both types of cable are similar, with very uniform impedance characteristics over the entire range of television bands.

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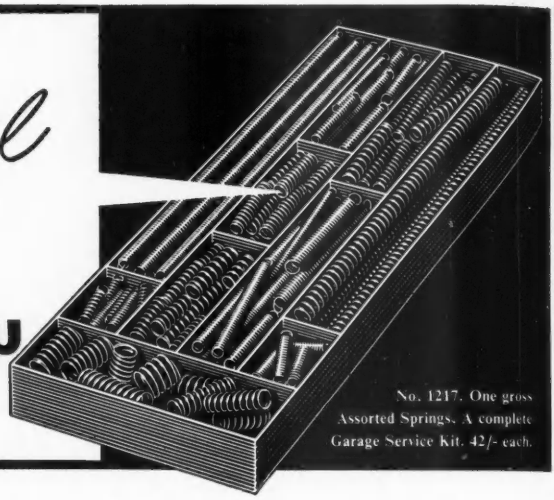

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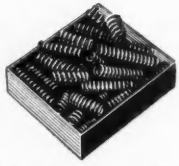

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ADDITIONAL ABSTRACTS

An Analysis of Metal Transfer in Gas-Shielded Welding Arcs

By W. J. GREENE

From *Applications and Industry* (*A.I.E.E.*), U.S.A., No. 49, July 1960, pp. 194–203, 13 illustrations.

THE commercial success of a metal-arc welding process depends in large measure on the mode by which molten metal is transferred from the electrode to the workpiece. At present, there is no formal theory of metallic transfer, although various aspects of the problem have yielded to analysis by quantitative methods.

In contrast with previous investigations, this paper approaches the subject on purely theoretical grounds, developing as much of the basic theory as is consistent with the mathematical model assumed in the development. In the interest of clarity, the theory is presented in three sections. The first section is limited to the formation and transfer of drops under the influence of gravitational forces and surface tension alone. These conditions are approximated in very-low-current arcs, where arc forces are negligible in comparison with the other forces present. In the second section, the formation and transfer of weightless drops is considered. In this case, arc forces and surface tension are the only forces acting to effect transfer.

The third section deals with all three forces. In this fully developed form, it is shown that terms can be collected into dimensionless groups, not unlike Reynolds, Prandtl, and Grashof numbers, facilitating computation in heat-transfer and fluid-flow problems. Thus, transfer in welding arcs can be characterized by two dimensionless parameters, i.e., the drop-size index and the transfer number. For satisfactory welding, the transfer number should lie within the range of 0·01 to 1. By means of these parameters, the transition current, as well as the drop size in the repulsion, pre-transition, and post-transition regions, can be determined.

It is emphasised that the theory in its present form applies only to arcs in which the current density at the active surface of the electrode is uniform and remains constant with changes in current. This condition is not satisfied in jet rotation arcs and in partially stabilized straight-polarity arcs where both cold and thermionic cathode actions are occurring simultaneously. It is also assumed that the surface tension, density, and electrode diameter remain constant with changes in temperature, as variations will produce corresponding variations in the values of drop-size index and transfer number over the welding-current range.

All phases of this theory have not been subjected to experimental verification. However, the variation of transition current with wire size shows good agreement with measured values. Drop sizes in the spray region are somewhat greater than measured values. This may be attributed to the fact that the current may not flow into the plasma normal to the molten electrode surface, as assumed.

In general, the theory leads to the conclusion that deterioration in transfer under certain conditions of welding can be attributed to excessive current density at the electrode surface. Final vindication of this point of view depends on the results of further research into anode and cathode phenomena and the factors controlling current density. An integral part of this effort is the development of more accurate methods for the measurement of electrode current densities.

The Tensile Properties of Some Engineering Materials at Moderate Rates of Strain

By R. F. STEIDEL, JR., and C. E. MAKEROV

From *ASTM Bulletin*, U.S.A., No. 247, July 1960, pp. 57–64, 15 illustrations.

THE dynamic strength of materials depends both on the permanent strain to which the material is subjected and the rate at which this strain is applied. For normal engineering materials this strength usually decreases with temperature and increases with strain rate. The fact that the ultimate strength of certain materials increases with speed has long been recognized. Also, many methods have been used to determine the dynamic strength of materials, including dropping weights, Izod or Charpy pendulum machines, rotary impact machines, and explosive impact testers. In general, only the explosive impact tester, or bomb tester, can be used for strain rates beyond 1000 in. per in. per sec.

In this report, details are given of an investigation at the lower strain rates, the materials tested comprising a cold-rolled steel, uranium, lead, six aluminium alloys, and six titanium alloys. Each material was tested at three static strain rates approximating 10^{-5}, 10^{-4}, and 10^{-2} in. per in. per sec on a standard Baldwin tension testing machine, and also at a strain rate of about 10^{2} in. per in. per sec on a modified Charpy impact testing machine, the major part of the report being concerned with an account of this latter test work.

As expected, all these materials showed an increase in yield strength, varying from a negligible increase in strength over the static strength in the case of one of the aluminium alloys, to an increase of 72·9% for the cold-rolled steel. It should also be noted that, while the aluminium and steel specimens showed a simultaneous increase in elongation for the dynamic case over the static, titanium showed a decrease in elongation with strain rate. This verifies the results of an investigation reported in 1955 and also in two recent reports on the tensile properties at high strain rates.

The investigation also showed that the true stress at fracture for steel and aluminium increases with strain rate. Titanium and titanium alloy evidence some loss in ductility with an increase in strain rate. Consequently, there is a corresponding decrease in true strain at fracture for titanium.

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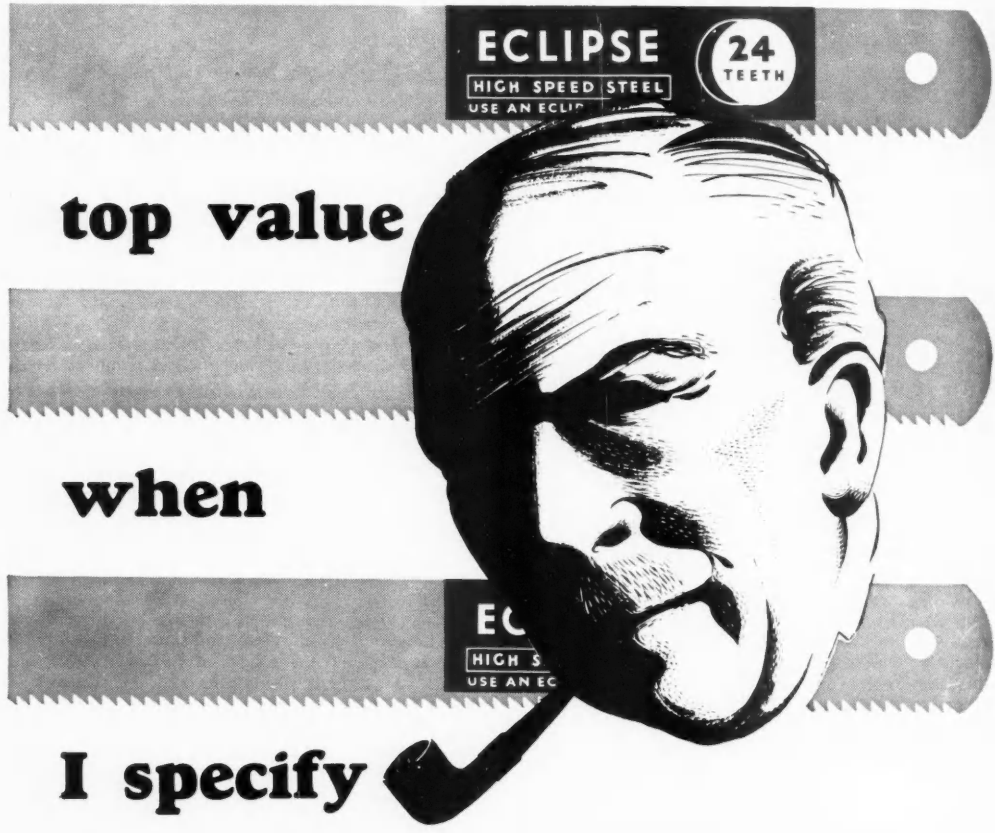

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New Alloys for Brazing Heat-Resistant Alloys

By W. FEDUSKA

From *Welding Journal*, U.S.A.,
Vol. 39, No. 7, July 1960,
pp. 292s-300s, 9 illustrations.

THE commonly used brazing alloys which fulfill most of the requirements for high-temperature brazing are nickel-chromium-silicon-boron-carbon alloys, nickel-chromium-silicon alloys, nickel-silicon-boron alloys, nickel-silicon-boron alloys, nickel-phosphorus alloys, and nickel-phosphorus-chromium alloys. These alloys perform very well in many applications, but may have some disadvantages in certain applications. Thus, the nickel-chromium-silicon-boron-carbon alloys, the nickel-silicon-boron, and the nickel-chromium-silicon alloys can react excessively at brazing temperatures to cause considerable base-metal penetration or erosion. If thin (0·020 in. or less) stainless-steel or high-temperature alloy components are to be joined, complete base-metal penetration by the brazing-alloy elements can occur. Stringent control of all brazing factors, especially preplacement, may enable large area joints to be prepared on thin sections of high-temperature alloys with these brazing alloys. Joints to thin-walled stainless steels can be made with little base-metal erosion when nickel-phosphorus or nickel-chromium-phosphorus alloys are used, but the resulting ductility of such brazed joints is low, may be harmful in cyclic stress applications, and must be improved by heat treatment. None of the nickel-chromium-silicon-boron-carbon,nickel-chromium-silicon, nickel-silicon-boron, nickel-phosphorus, or nickel-chromium-phosphorus alloys can, *per se*, readily wet and adhere to titanium-aluminium bearing alloys or high-aluminium iron-base alloys. Brazing of titanium-aluminium bearing alloys with nickel-chromium-silicon and nickel-silicon-boron brazing alloys can be accomplished but requires, when surface conditioning is not used, specific conditions of vacuum and temperature which may not always be attainable in production.

The investigation described in this paper was undertaken to develop a ductile brazing alloy, or alloys, which might possess superior wettability and produce ductile joints with various stainless steels, titanium-aluminium-bearing alloys, or aluminium-iron type alloys, without reacting excessively with these materials. This paper relates the development of these alloys and presents some property data obtained on joints brazed with the best of these alloys.

Various low-melting alloys have been developed, these alloys having a nickel-palladium base and containing additions of beryllium and/or silicon. Of these, the most promising alloy, containing 0·25% Be, 0·49% Si, 44·3% Ni, and 54·96% Pd, has a melting-temperature range of 2040° to 2120° F, is workable into thin strip stock, produces superior wetting of titanium and/or aluminium-bearing high-temperature alloys, causes little base-metal penetration or erosion during the brazing of thin-walled, wrought materials, has adequate shear strength to 1500° F, and exhibits room-temperature ductility in brazed joints of various base metals.

Characteristics of Audible Noise from Power Transformers

By M. W. SCHULTZ, JR., and R. J. RINGLEE

From *Power Apparatus and Systems* (*A.I.E.E.*), U.S.A.,
No. 48, June 1960,
pp. 316-323, 6 illustrations.

THE need for consideration of audible noise from power transformers in the planning of power systems has been well recognized for many years. Various criteria have generally been applied voluntarily, and have developed as a result of physiological research into auditory masking and loudness sensation, and of studies of community noise problems, such as jet aircraft and automobile traffic.

Audibility criteria, which provide a consistent basis for acceptable intruding noise levels, measure the loudness of the intruding noise in the presence of the background or ambient noise. In addition, several of these criteria attempt to measure annoyance by taking into account the temporal character of the intruding noise, as well as the previous exposure of the listener.

To measure the loudness of an intruding noise requires a knowledge of the amplitude and frequency distribution of both the intruding noise and the background noise. Accordingly, in this paper a description is offered of several audibility and acceptability criteria and a specific acceptability criterion for application to the evaluation of transformer loudness. In addition, the use of various frequency analysers to measure the level of transformer harmonics in the presence of background noise is discussed, together with statistical data on the nature of transformer noise. Harmonic-amplitude data on full-scale transformers and far-field polar noise-distribution data on scale models are included, as well as data on the propagation of the significant harmonics with distance.

The data presented in this paper are intended to assist power system designers in arriving at specifications for permissible transformer sound levels in cases where the present standards are not adequate.

The criterion for forecasting public response to noise proposed by Stevens, Rosenblith, and Bolt has been simplified to apply to transformer noise problems and a refinement has been added to account for the varying influence of ambient masking on loud noise, as compared with noise only slightly louder than ambient. It is proposed further to simplify the problem of measuring the loudness of transformer hum (core noise) in the presence of background noise by the use of a set of plug-in band-pass filters with pass bands equal to the ear's critical bandwidth and distributed about the major transformer harmonics.

Statistical data are given of the frequency composition of transformer-core noise and cooling-fan noise and are compared with typical ambient spectrum levels. In general, core noise is more limiting than fan noise from an audibility standpoint; accordingly, it is proposed that core noise and cooling-fan noise be specified separately.

The variance of individual harmonics of transformer noise is greater than for the total transformer noise, so that a specification limiting the individual harmonics is more severe than one limiting the total transformer noise.

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Methods of Hardness Testing for Cold-Rolled Carbon and Low-Alloy Steel Strip

By G. MOLINDER

From *Jernkontorets Annaler*, Sweden,
Vol. 144, No. 4, 1960,
pp. 297-328, 18 illustrations.

As reported in this paper, some of the different hardness-testing methods have been studied with respect to their applicability and accuracy for testing cold-rolled steel strip of different thicknesses and hardnesses, and the possibility of reliable conversion from one hardness scale to another has also been investigated. In addition, tensile tests were made, the determination of ultimate tensile strength being regarded as an alternative method of ascertaining the hardness of steel strip. The specimens used consisted of cold-rolled strip of carbon steel and low-alloy steel in the annealed, cold-deformed, and hardened and tempered condition.

It was found that only two methods can be applied to all dimensions and to almost all hardness states, these methods being the determination of tensile strength and Vickers testing on cross-sections. Of these two methods, the tensile test gives the most accurate results and the least spread, provided that the hardness does not correspond to a higher tensile strength than about 200 kg/mm^2. Correct and reproducible results can, however, be obtained up to about 230 kg/mm^2 if the specimens are prepared with exceptional care. The main objection to the method is that it requires relatively long specimens and therefore cannot be used for testing small details made of cold-rolled strip. Tensile-strength figures can only be translated into other hardness scales if the composition and condition (annealed, cold deformed, or hardened) of the strip are known.

Vickers testing requires a good deal of care and judgment and cannot generally be effected on the surface of strip. A cross-section has to be prepared in order to avoid the influence of surface effects. The main advantages of the Vickers method are that it can be used for any hardness and thickness of strip and that the Vickers figures can be converted to other hardness scales without regard to steel composition, heat treatment, or cold deformation.

Rockwell testing methods have a number of disadvantages which must always be taken into consideration. Thus, the surface zone of commercial steel strip is generally not representative of the bulk of the material, while Rockwell methods—especially Rockwell C and Rockwell B methods—require such high loads that their use for thin steel strip is very limited. Furthermore, each of the Rockwell methods can be used only within a fairly narrow hardness interval. Rockwell methods can nevertheless be used with great advantage, especially for investigating the uniformity of a certain strip product.

Some general recommendations are given for conversion of hardness values from one scale to another, the most important recommendation, however, being that conversion should be avoided, if possible. If converted figures are given, it is considered definitely advisable to quote the original figure as well.

Supersonic Determination of the Relative Amounts of Graphite and Carbide in Iron Rolls

By P. BAKER

From *B.C.I.R.A. Journal*, Birmingham, England,
Vol. 8, No. 4, July 1960,
pp. 506-513, 4 illustrations.

THE non-destructive method of testing based on the transmission of high-frequency or supersonic sound waves through metals has become well established for the detection of cracks and other internal defects. The microstructure of the casting influences the scatter of the sound waves, and some knowledge of the material to be tested is necessary when selecting the most suitable frequency. For large castings having a coarse heterogeneous structure, this would be lower than that selected for wrought products having a finer and more homogeneous structure. Structures of castings up to 50-in. diameter are relatively coarse, and large-diameter quartz-crystal mosaic probes with a frequency of 0·5 Mcs are used to give adequate penetration.

In this paper, an account is given of the development and application of a supersonic test for the rapid determination of the degree of white-iron formation in the barrels of indefinite chill rolls and clear chill rolls. A brief description of the metallurgical characteristics of these rolls is followed by quantitative results, which include a relationship between surface hardness and white-iron formation in rolls, expressed as a velocity factor. White-iron formation expressed in this manner is also related to chill test samples cast with the rolls.

The supersonic test is normally applied to determine the soundness of castings, but the results given in this paper give an indication of the way in which it has been extended to provide a rapid estimation of the relative amount of carbide and flake graphite in the barrels of chilled rolls. The supersonic test is being applied on a routine basis to all straight cast indefinite chill rolls having a pearlitic matrix, and sufficient results have become available for the formulation of a standard in most diameter ranges. The test gives a rapid indication of the consistency of the product when considered with the surface hardness. The extensive application of temperature measurement to furnace and ladle metal has assisted in the detection and control of the factors which have proved to be mainly responsible for variations in hardness, namely, melting time and temperature.

The test is also applied to small straight carbon clear chill rolls, to determine their soundness and also the whiteness in depth. It has not been possible to determine the depths of clear chill by means of this equipment, but the indication of whiteness in depth is possibly of greater value, because depth of clear chill does not necessarily give a true indication of the mottle spread.

Exploratory tests on spheroidal-graphite chilled iron rolls have shown that the sonic velocities approach those of steel even in grey sections, and it is therefore unlikely that tests on this indefinite chill type of material will give the same indication of whiteness as in the flake-graphite qualities.

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"Self-Protecting" Ceramics for Hypersonic Flight

Following a research programme sponsored by the Boeing Airplane Company, of Seattle, Washington, a new ceramic graphite-base material, designated a "composite graphite body" has been developed. Because this new material, which at present has been produced on an experimental basis only, spontaneously forms its own protective coatings against elevated temperatures and oxidation, its potentialities for use in hypersonic flight are under investigation. The maximum tension and compression capabilities of the material are about twice those of standard graphite at room temperature, and it also has an advantage insofar as strength is concerned at temperatures above 3000° F. When suddenly exposed to high temperatures, the protective layer forms immediately—an important consideration in advanced flight concepts, where re-entry and other conditions often involve rapid and extreme temperature changes.

A typical composition consists of 50% graphite, 24% molybdenum disilicide, and 25% titanium boride by weight, plus minor ingredients to promote bonding. The protective layer develops at around 2200° F, appearing in one composition as a smooth, adherent, non-porous, yellowish-brown film about 0·001 in. in thickness. As the temperature and exposure to oxidation increase, the layer thickens and becomes more resistant, the ultimate thickness depending upon the combination of time, temperature, and oxidation.

Admittedly, much still remains to be learned about the material, and it is hoped that data on the mechanics by which the coating is formed can be utilized for a number of high-temperature materials now being developed by the company. Current work with these composite graphite bodies is concerned with making them usable for long periods at temperatures of more than 3000° F.

Trunnion Machine with Individually Accelerated Spindles

A range of new trunnion machines with several different feed rates for individual tools or groups of tools mounted on a single hydraulic feed unit has been developed by the Cross Company, of Detroit, Michigan. By using accelerated spindles to obtain different feed rates, individual operations can be set up for optimum surface finish, minimum tool costs, and maximum tool life.

A typical trunnion machine of this type (Fig. 1) is used for processing combination clutch and brake master cylinders, which require drilling, spot-facing, hollow milling, and reaming. All the tools are mounted on a single head, as shown in Fig. 2, and are easily accessible when the head is drawn back. This machine follows a normal cycle, workpieces being manually loaded and mechanically clamped in fixtures on the trunnion, after which the trunnion is indexed and the head advances rapidly and then enters the feed stroke. The majority of the tools feed at the basic rate of the feed unit, but several quills feed out more rapidly.

The accelerated spindles have an idler pinion fixed in the head, this pinion meshing with two racks, one of

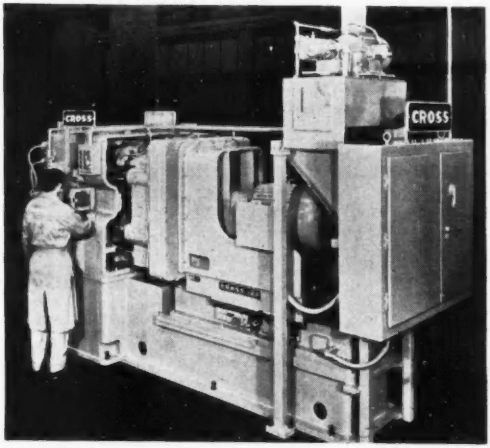


Fig. 1

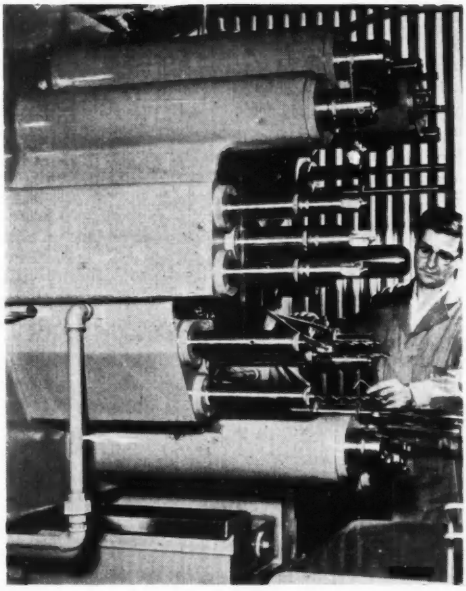
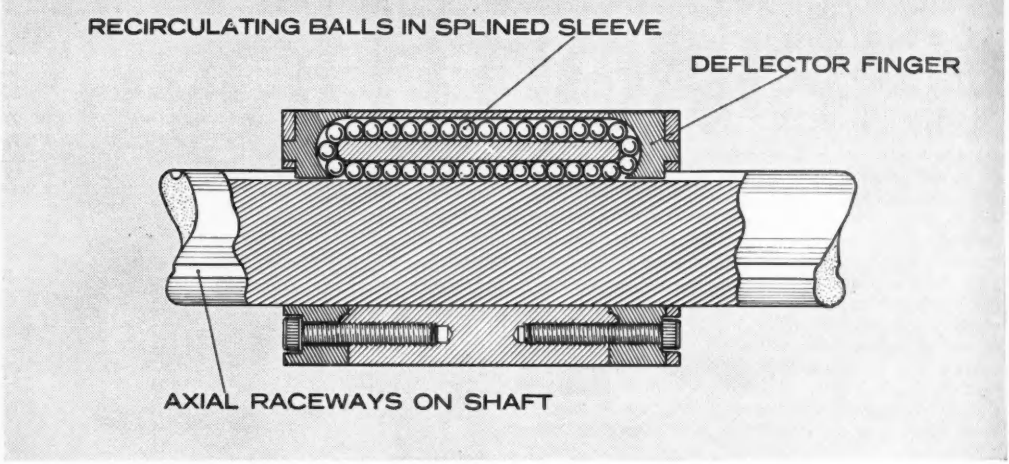


Fig. 2

Beaver ball splines, over 90% efficient, operate at -55°C to 450°C and over . . .



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Machined and ground to the highest standards of precision, Beaver ball splines are much more efficient in operation than conventional splines. They substitute a recirculating stream of precision-ground balls, rolling along specially contoured grooves, for the solid key and keyway. This arrangement reduces friction to a minimum when the spline assembly is subjected to linear, torque and bending loads. It also gives optimum smoothness and a very fine degree of positioning accuracy. When compared to conventional spline mechanisms, Beaver ball splines require a much smaller power source; provide a predictable operational life; need much less maintenance; and give long, trouble-free operation.

Basic design applicat'on analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification and each unit is specially designed for its particular application. For Beaver splines can be made with angular pre-loading, with multiple circuits, and with telescopic extensions. Beaver splines have been proved as the most efficient method of minimising friction when high torsional and bending loads are imposed during linear movement in many engineering applications. They have been designed already with rated operating torque capacities of 50,000 lb/in (200,000 lb/in maximum static torque) but the maximum potential operating torque is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball screws

reduce the power required for actuation by as much as 80%. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion when converting rotary drive into linear output.

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which is cut in the quill, which contains the spindles, and the other in an actuator bar. At the end of the rapid-advance stroke, the actuator bar contacts a stop on the trunnion and ceases moving. As the head feeds, the centre of the pinion moves along the actuator bar, causing the pinion to rotate and feeding the quill out with double the rate (and stroke) of the feed unit. A spring at the end of the actuator bar keeps the quill and the bar in their retracted positions. When the actuator bar stops moving, this spring is compressed by the continued movement of the head. When the feed unit starts to retract, the spring causes the quill to be returned to its starting position.

Feed rates other than double are achieved by the use of a differential pinion. Two pinions are attached together on the same axis, one meshing with the rack in the actuator bar and the other with the rack in the quill. Depending on the diameters or sizes of teeth in the pinions, feeds can either be greater or less than the rate of the hydraulic feed unit.

Direct Flow Indicators for Lubricants

The use of highly detergent oils in the mechanical lubricators of diesel engines has given rise to the problem of fouling of the sight-glasses. In fact, since the introduction of additive oils, the difficulty of indicating small flows has become increasingly apparent. Thus, in some cases, the characteristics of the oil are such that the conventional type of flow indicator will not work at all, while, in other cases, reasonable results can be obtained only if the glasses are removed at frequent intervals for cleaning and maintenance.

The Muntz direct flow indicator has been specially developed by Alan Muntz & Company Limited, of Feltham, Middlesex, to overcome these difficulties and is stated to provide a complete solution to the problems of flow indication associated with the use of additive oils. The new indicator, which is neat, compact, and easy to read, comprises a ball in a transparent tube with a tapered bore, so arranged that, as the flow increases, the ball rises in the tube, thereby providing an indication of the actual flow rate. The indicator, which is designed to operate at pressures up to 1000 psi, contains no special liquids, so that contamination of the oil is impossible, and fitting presents no difficulties. All components are manufactured to close tolerances and are fully interchangeable.

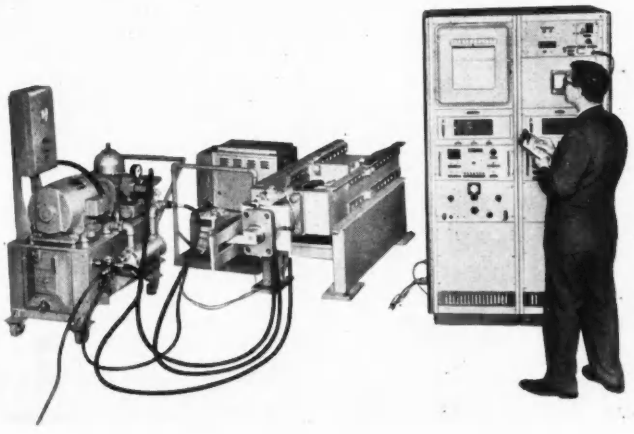
Three different types are at present in production, i.e., a standard single indicator, suitable for inclusion in any oil line; a replacement indicator, which can be substituted directly for other types of sight-glasses; and a multi-point panel, which is an extremely compact arrangement designed for use where a large number of indicators must be used. All the units are grouped together, making it possible to check the various flows virtually at a glance. The standard multi-point panel contains 28 units, mounted in two banks of 14 units each, one above the other, and measures approximately $14 \times 6 \times 1\frac{3}{8}$ in., though other sizes can be supplied to special order. The standard flow indicator is suitable for flows of from 0·2 to 4·0 cc/min, and the replacement indicator for flows of from 0·1 to 2·0 cc/min.

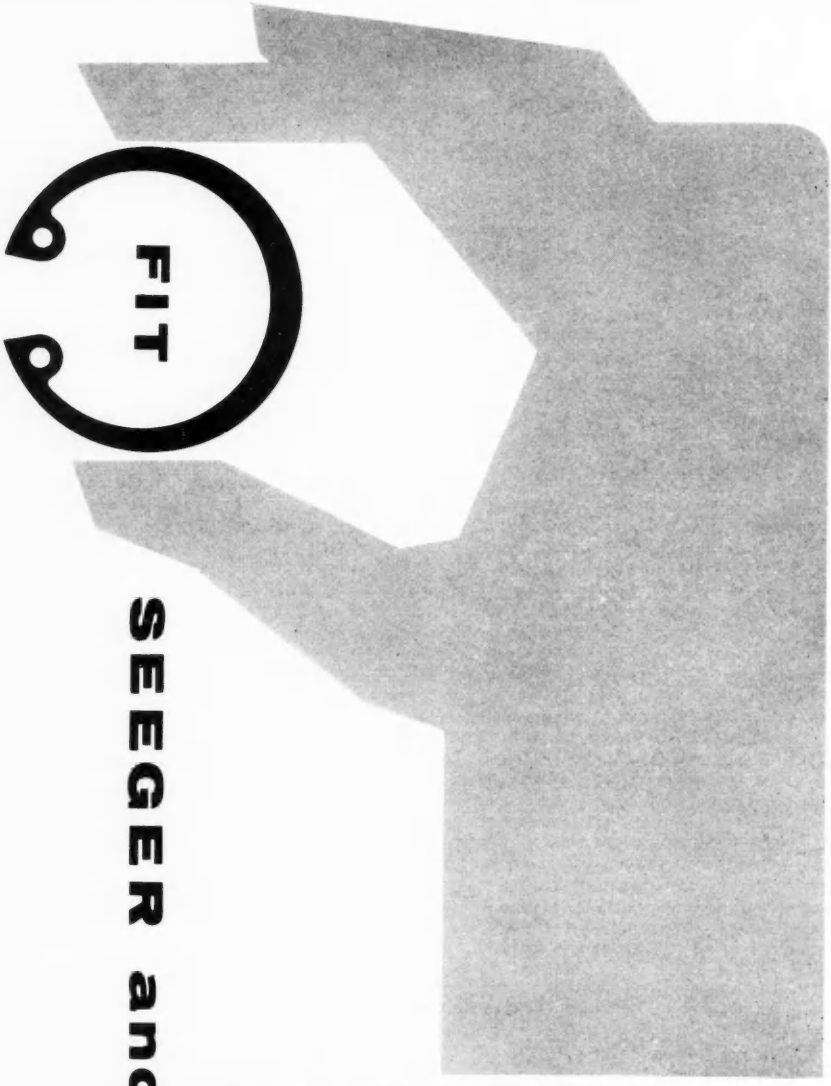
Electro-Hydraulic Materials-Testing Machine

A new materials-testing machine for advanced cycling or fatigue testing of specimens or structures under compression-tension and elevated-temperature conditions has been introduced by the CompuDyne Corporation, of Hatboro, Pa. Designated the "Dynatest", the machine is capable of cycling up to 20 cps and of following a typical programmed heating rate of 200° F/sec, the maximum heating rate depending on the configuration of the specimen.

The "Dynatest" machine is an electro-hydraulic unit with individual closed-loop systems for force and heat loading. A high-speed ram delivers a stroke up to 8 in. at a velocity of 1 ips at rated load. The standard force-loading channel has multiple ranges from 200 to 50,000 lb full-scale, a selector switch permitting ranges to be changed without mechanical adjustment. However, higher force-loading ranges are available on order. The steady-state accuracy of the force-loading system is $\pm 0{\cdot}5\%$ of the selected range, with a dynamic accuracy within $\pm 1\%$ of the selected range. The temperature-loading channel has a range up to 3000° F and can be furnished with either radiant, resistive, or inductive heating, or any combination of heat sources. Manual and programming control are provided for each of the loading systems. A master-programme button permits the temperature- and force-loading programmes to be started simultaneously. The programming speed is 4 cps.

The machine basically comprises four units, i.e., a control panel, a hydraulic pump, a specimen-holding frame, and an ignitron unit, all being carriage-mounted for maximum flexibility, with the exception of the frame, which is designed so that the hydraulic cylinder and load cell can be removed for structural testing. The pump unit is effectively isolated from vibration by being packaged separately. Standard read-out equipment consists of temperature, load, deflection, and strain





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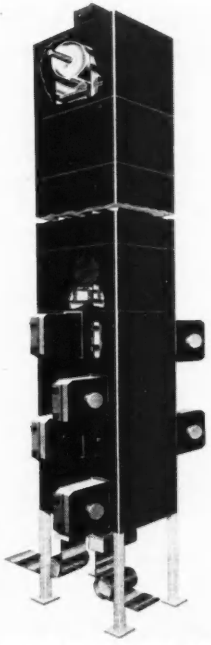
recorders, though other output arrangements are available. Safety features include the use of flame-resistant hydraulic fluid and automatic shut-down for fail-safe protection. Special cylinder seals, with collection and return piping, are provided for minimum leakage and maximum cleanliness.

Furnace for Continuous Bright-Annealing of Stainless-Steel Strip

Claimed to permit bright-annealing at production rates as high or even higher than existing annealing and pickling lines, but at about half the cost, a new high-production furnace for the continuous bright-annealing of stainless-steel strip has been developed by the Industrial Heating Department of the General Electric Company, of Western Springs, Illinois. It is stated that the strip has improved surface appearance, corrosion resistance, and physical properties. Also, the vertical construction of the furnace reduces the amount of floor space normally required and ensures that minimum tension is placed on the strip during annealing. The strip is heated and cooled during the single downward pass through the furnace, where it touches nothing but a pure and dry atmosphere while at elevated temperatures. The high tensions associated with horizontal catenary furnaces, which can reduce gauge and width and can distort the strip, are not required.



In operation, stainless-steel strip is fed into the furnace in an inverted-U pattern after it has been cold-rolled, the strip moving up the rear side of the furnace, and then over a top roll and downwards for the heating and cooling pass. On the downward pass, the strip first enters a heating chamber with no muffle, where it is rapidly heated to annealing temperature by direct radiation from molybdenum heating units. A high-purity insulation system permits operation of the furnace at a high temperature. After reaching the annealing temperature, the strip moves down into the adjacent cooling chamber, where it is rapidly cooled by high-velocity hydrogen or dissociated ammonia. This specialized high-velocity, jet-cooled system forces the atmosphere against the strip at a right angle. As the atmosphere strikes the strip, a "scrubbing" action is produced which speeds cooling. The atmosphere is cooled by recirculation through water-to-gas heat exchangers. The jet-cooling principle employs a number of self-contained, independent units with individual motors and heat exchangers, which force the atmosphere against the strip. Each of these units is easily accessible for maintenance and inspection during operation. When the strip reaches the delivery end of the furnace, it is cooled to a temperature of 200° F, and is ready for coiling. The exit seals are the first surface the strip touches after leaving the top roll on the downward pass.

These furnaces are manufactured in two heights, i.e., about 54 and 75 ft, and in sizes suitable for processing strip widths of 12, 24, 36, and 48 in. In a typical application, involving the annealing of Type-430 stainless-steel strip, 0·02 in. in thickness and 24 in. in width, at 2000° F, the furnace can handle 60 fpm of material, representing a capacity of about 6000 lb/hr.

Direct-Writing Oscillograph Recorder

A new direct-writing oscillograph introduced by Savage & Parsons Ltd., of Watford, Herts., is capable of recording at frequencies up to 1000 cps and above, and provides a choice of eight paper speeds, from 5 ipm to 150 ips, giving a well-defined trace at writing speeds in excess of 12,000 ips. Designed as a 12-channel unit, the recorder is available with matched amplifiers and power-supply units, if required, and is able to record any varying function which can be translated into an electrical signal within the frequency range. It is therefore of value in a large number of industrial applications, ranging from stress analysis by electrical strain-gauge techniques to the direct recording of electrical power-supply characteristics.

The magnet block carries 15 specially made pencil-type mirror galvanometers, the additional three channels serving for time or event marking, or as extra recording channels, if desired. By operation of a switch, two of these three galvanometers can be connected with the mains supply to give a reference frequency. The oscillograph employs a compact ultraviolet lamp, recording up to 15 traces on sensitized paper, 6 in. in width, the images being developed spontaneously within a few seconds. Rolls of recording paper, containing up to 200 ft, can be loaded through a front panel, and feeding is automatic, once the edge of the paper has been placed in contact with the drive roller. A footage selector switch is provided to stop the drive after 2, 5, or 10 ft of paper have been exposed, or to allow continuous running.

Paper speeds are selected by push-buttons on the front panel, and are indicated by a light opposite the appropriate button. All gears are permanently meshed, so that speeds can be changed during recording, and there is a minimum of delay in reaching even the highest speeds. The position of each trace on the paper can be simply adjusted through an opening in the top cover, using a screwdriver, while the resulting change on the paper is observed through the front window. If less than the full number of channels are in use, unwanted traces can be directed off the edge of the paper. To identify

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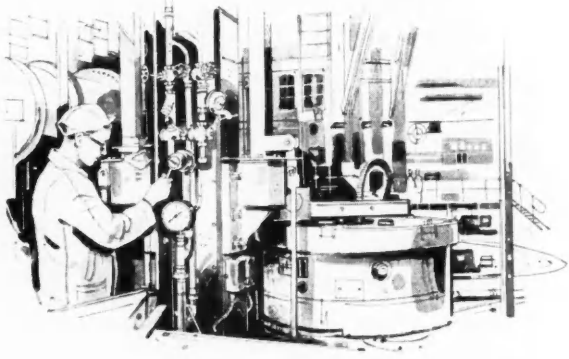

These are specific examples. Your use of Leonard Thermostatic Steam Water Heaters will probably be different. Write for help. (Our folder H/24)

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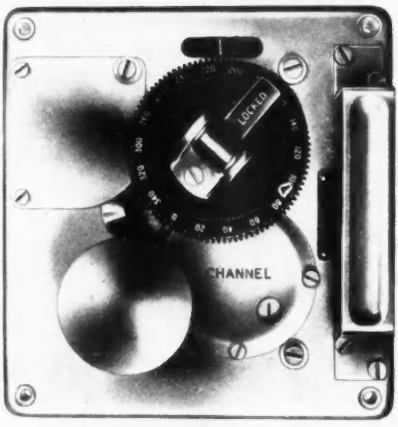
the traces, a sequential interruption of each trace provides identification of each channel at intervals of 2 ft, irrespective of paper speed.

Five types of pencil galvanometer are available with the oscillograph, the standard general-purpose type giving a response up to 1000 cps with a tolerance of ±1% and a sensitivity of 7·5 mA/cm. Other galvanometers, permitting recording frequencies up to nearly 2000 cps, are also available. The amplifiers and power-supply units have been designed specifically for the oscillograph and, if required, can be assembled into modules for desk or rack mounting.

Rotary Position-Selector Unit

A remote-controlled device, with applications in many fields where it is required to rotate a shaft with a high degree of accuracy, has been developed by The Plessey Company, of Ilford, Essex, in conjunction with the Ministry of Supply, for use with multi-channel transmitters and receivers. Weighing approximately 2¼ lb and with an operational temperature range of from −40 to +70 C, the unit is designed to rotate a shaft to any one of twelve positions, each position being set up independently with an accuracy of within 6 minutes of arc.

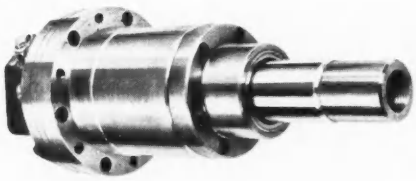


Visible indication from the front of the unit shows the selected position, and a built-in switch can be used for confirming the position to the remote-control site. An additional built-in switch permits a number of selector units to be operated in sequence. The unit is available for operation on 12 to 48 V d.c. in two panel sizes (4 × 4 in. and 3¼ × 4⅛ in.), and with a torque of either 35 or 60 oz-in.

Automatic Hydraulic Oscillator

A new hydraulic oscillator developed by Hydraulic Machinery Drives Ltd., of Reading, Berks., a subsidiary of Keelavite Hydraulics Ltd., of Allesley, Coventry, is designed to impart automatically a regular oscillation to any piece of equipment under a controlled stroke and frequency, a typical application being the operation of the "doctor" blade of photogravure printing machines and paper-making machines.

The oscillator, which is of robust construction and which has an integral flange mounting, basically consists of a double-acting cylinder with a stroke of from ¼ to 2 in. in increments of ¼ in. The cylinder bore is accurately honed to a mirror finish, and the piston rod is precision-ground. Reciprocation is achieved by means of a built-in pilot-operated directional valve which supplies pressurized



oil alternately to each side of the piston, the speed of the stroke being capable of variation between 6 and 60 strokes per minute. By means of a small flow-control valve, it is possible to make the speed of reciprocation independent of load changes. The maximum working pressure of the hydraulic oil used is 1000 psi, the maximum flow requirement being 1¼ gpm for a 2-in. stroke at 60 strokes per minute. The maximum force available in either direction is 1 ton.

The Future of Air-Cushion Craft

(*Concluded from page 110*)

to carry as high a payload as that of a ship without the need for deep water, and that it has a long range without requiring the landing facilities of an aircraft. On the other hand, it requires a higher specific power than a displacement vessel and is far slower than an aircraft. On this basis, Fig. 2 indicates how air-cushion craft may develop, from the point of view of power/weight ratio in terms of speed, to fill a gap in the transportation spectrum at present comprised by ships, planing boats, hydrofoil boats, helicopters, and aircraft.

Insofar as payload is concerned, the air-cushion craft covers roughly the same payload-speed range as the helicopter, as illustrated in Fig. 3 which shows payload/weight ratio as a function of speed for hydrofoil boats, passenger and cargo ships, helicopters, aircraft, and air-cushion craft. At first glance, the air-cushion craft would appear to be in direct competition with the helicopter, but there are, in fact, many important differences between these two forms of transport. Thus, while the air-cushion craft has a greater range potential, is considerably less expensive to operate, and increases its efficiency with size, the helicopter can far more easily cope with surface obstacles and, indeed, can fly at high altitudes.

In conclusion, it may be stated that it is almost certain that some of these air-cushion craft will be accepted as practical and useful vehicles within ten years. However, the extent of their acceptation will depend on finding applications for which higher over-water speeds are imperative, or are at least highly desirable, and in this connection it appears that their first uses will most probably be military.

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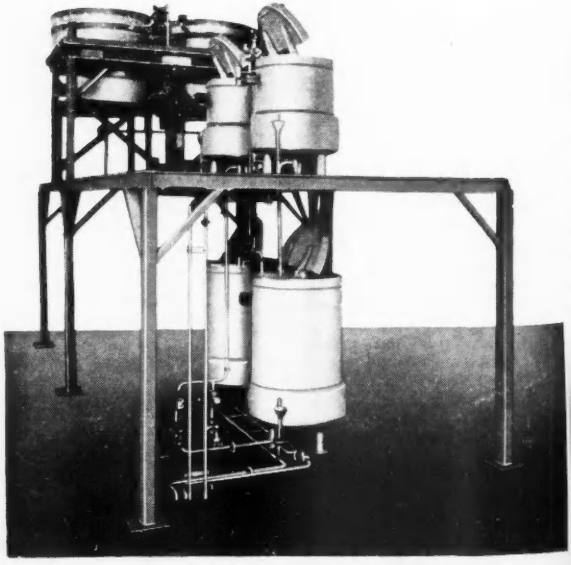

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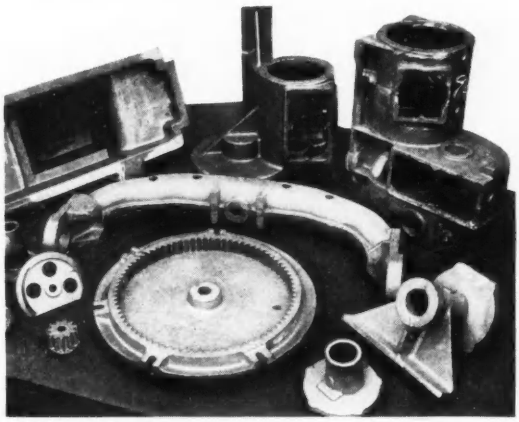

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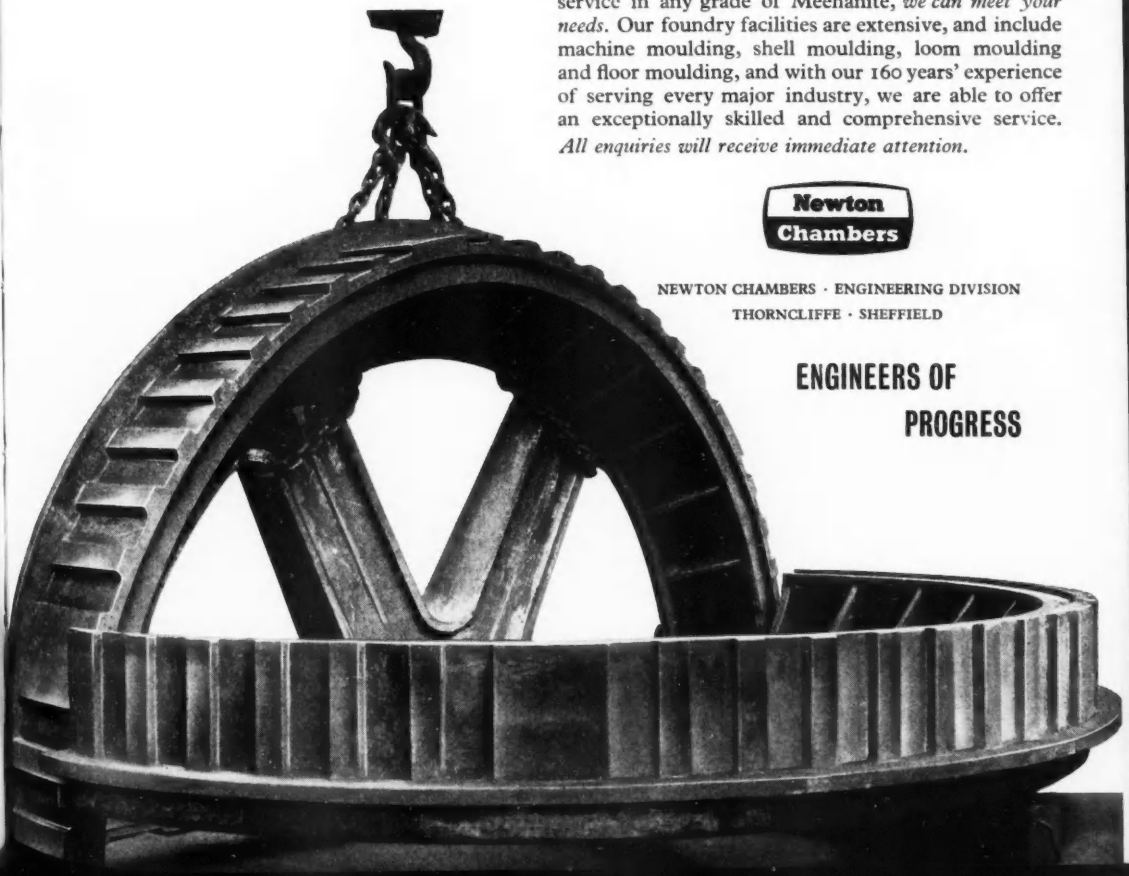

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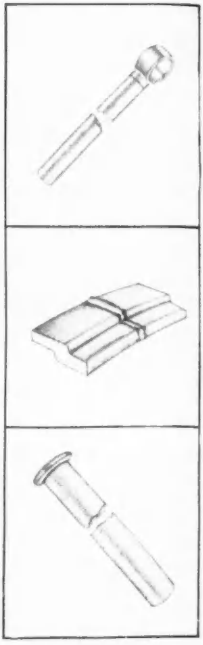

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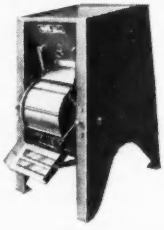

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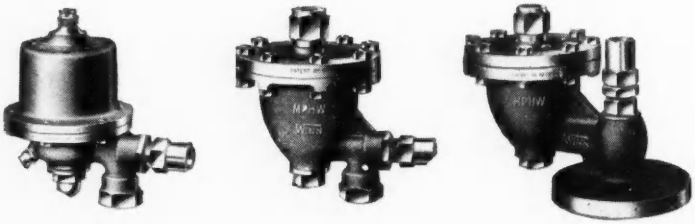

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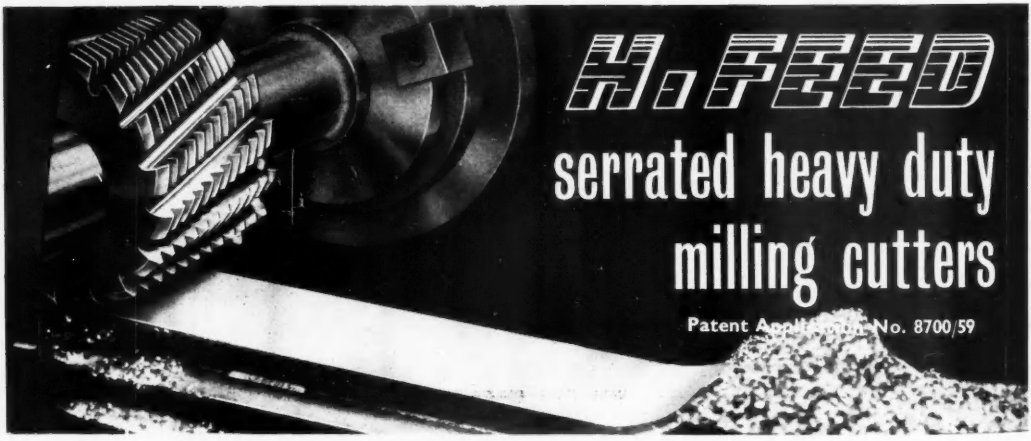

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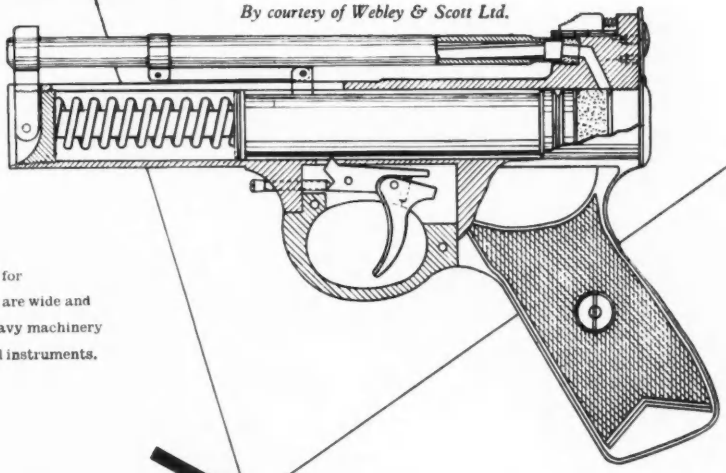

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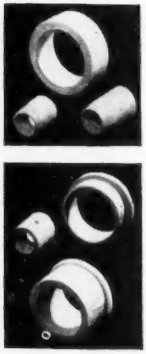

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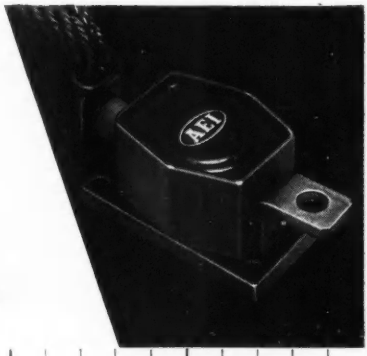

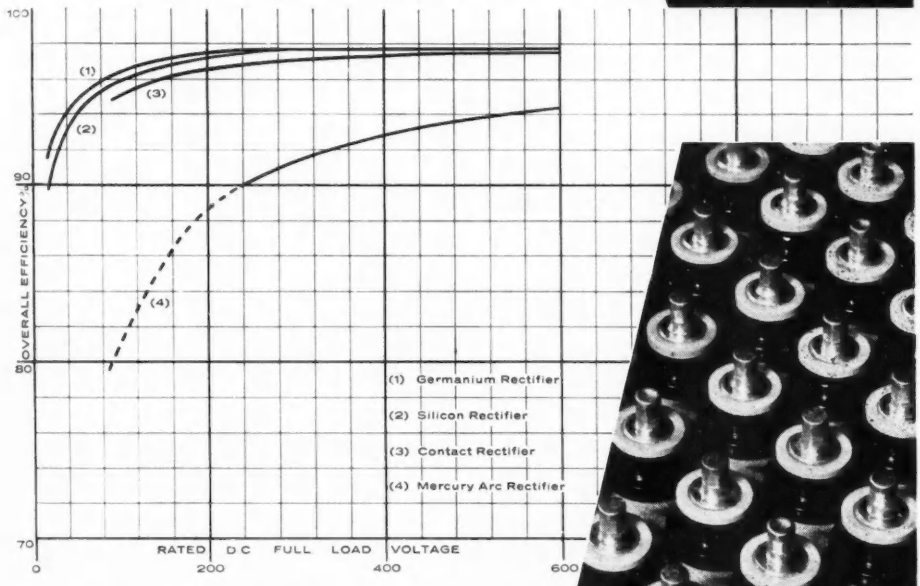

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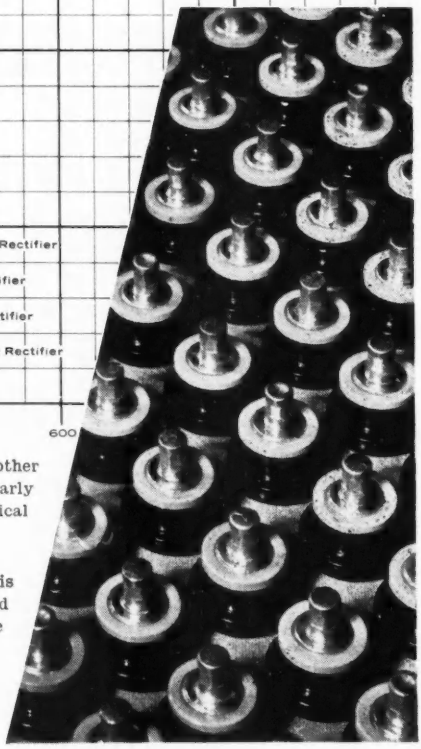

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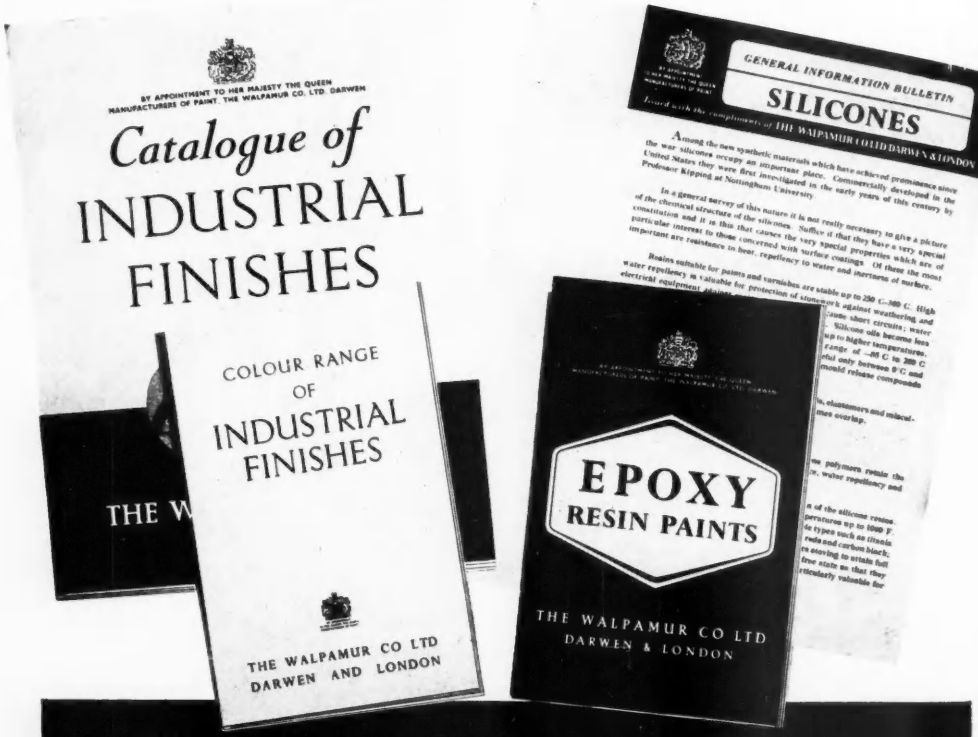

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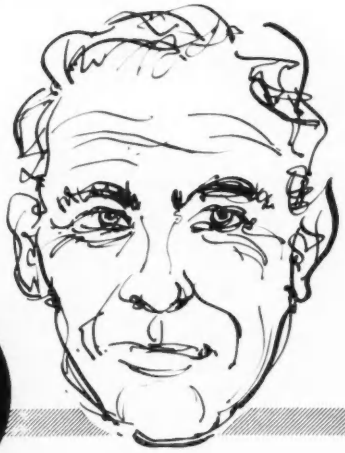

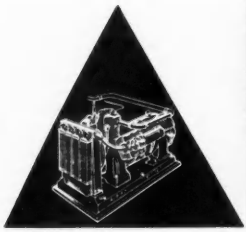

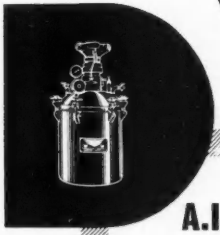

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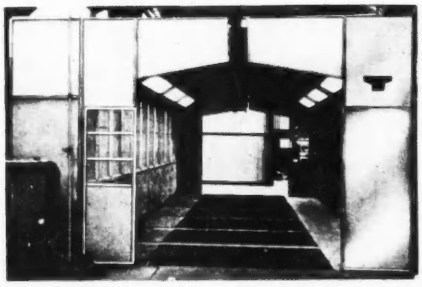

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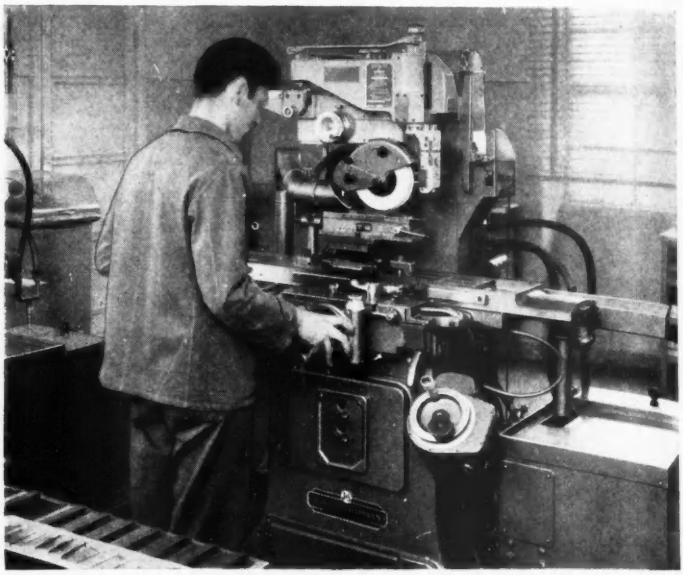

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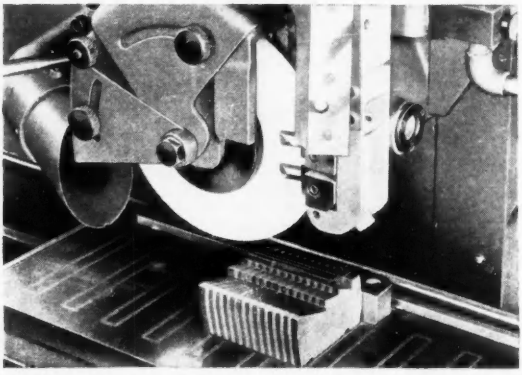

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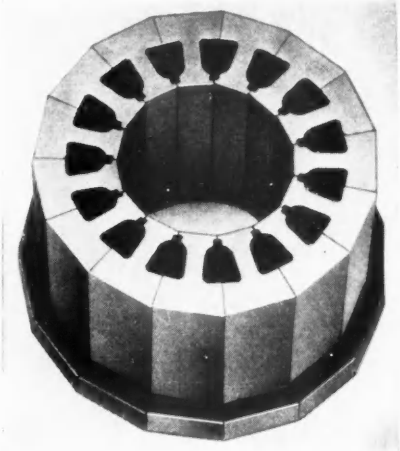

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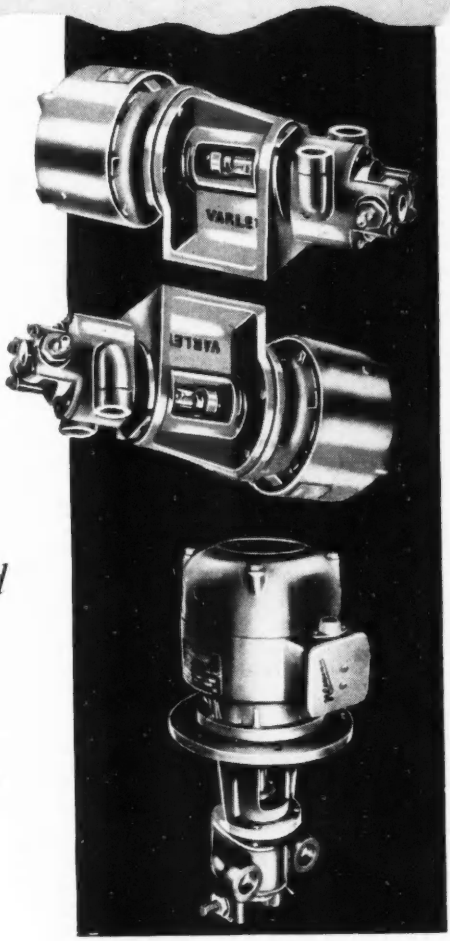

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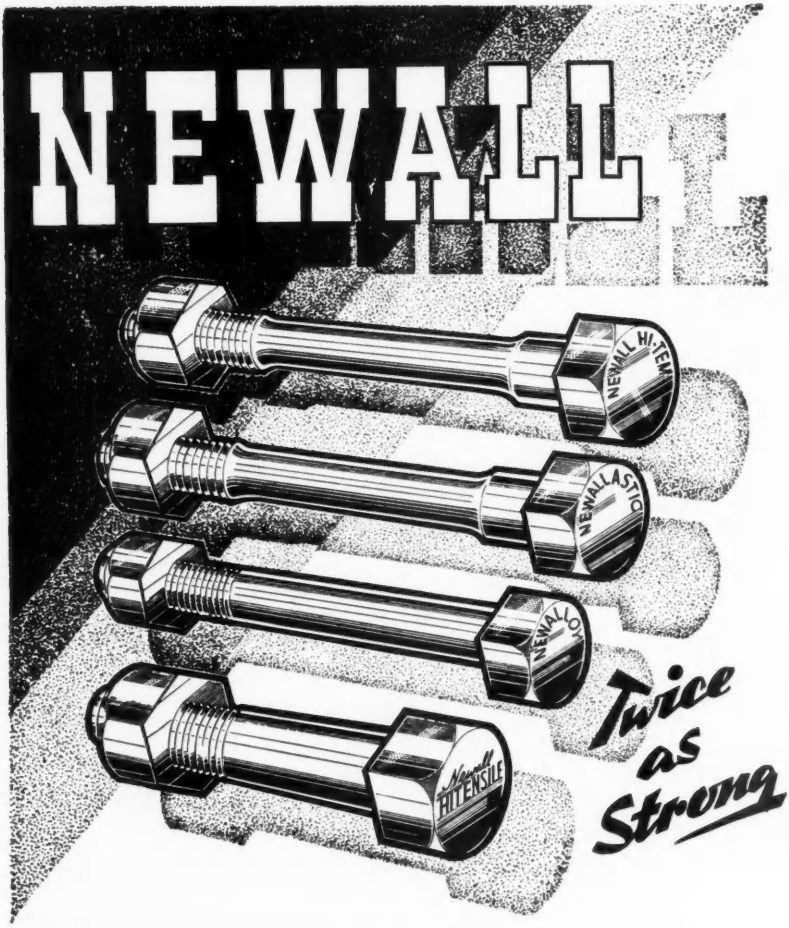

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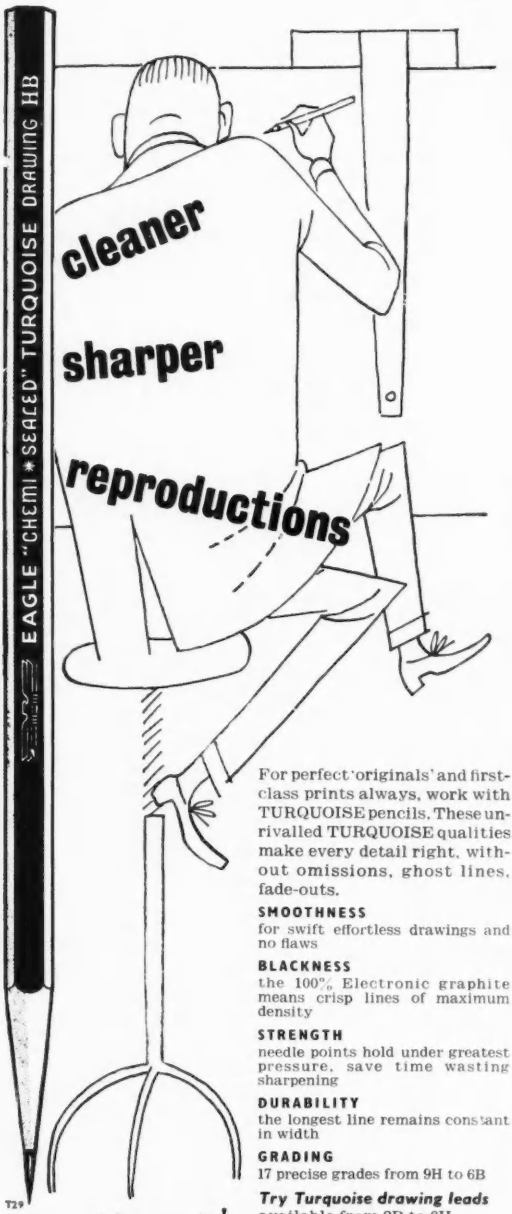

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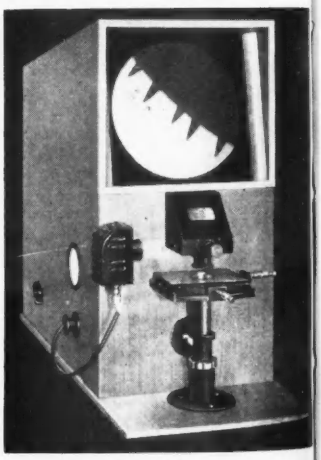

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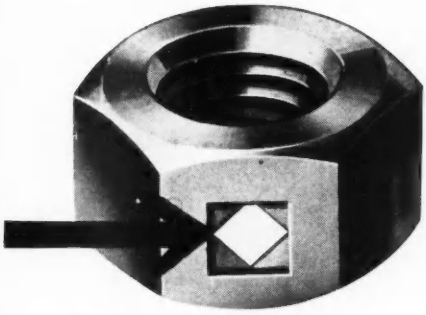

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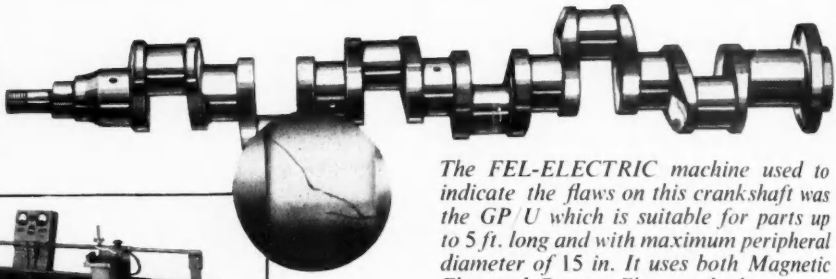

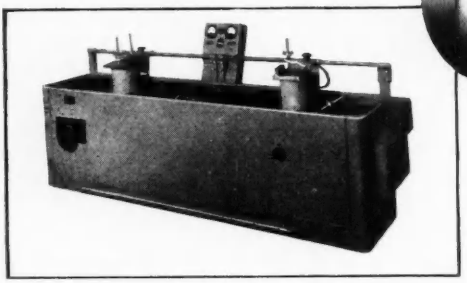

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3	2.89	4.08	5.00	5.75	7.07	8.66	10.0	12.9
5	2.24	3.16	3.86	4.77	5.48	6.71	7.75	10.0
7.5	1.82	2.56	3.16	3.65	4.47	5.48	6.32	8.17
10	1.58	2.24	2.74	3.16	3.88	4.74	5.48	7.07
15	1.29	1.83	2.24	2.58	3.16	3.87	4.47	5.78
25	1.00	1.41	1.73	2.00	2.45	3.00	3.46	4.47
50	.707	1.00	1.23	1.41	1.73	2.12	2.45	3.16
75	.578	.818	1.00	1.15	1.41	1.73	2.00	2.58
100	.500	.707	.866	1.00	1.23	1.50	1.73	2.23
150	.408	.575	.707	.818	1.00	1.22	1.41	1.82
200	.354	.500	.612	.707	.866	1.06	1.22	1.58
350	.268	.378	.463	.535	.655	.803	.926	1.19
500	.224	.316	.388	.447	.548	.671	.775	1.00
1,000	.158	.224	.274	.316	.388	.474	.548	0.708
1,500	.129	.183	.224	.258	.316	.387	.447	.578
2,500	.100	.141	.173	.200	.245	.300	.346	.448
5,000	—	.100	.123	.141	.173	.213	.245	.315
7,500	—	.081	.100	.115	.141	.173	.200	.258
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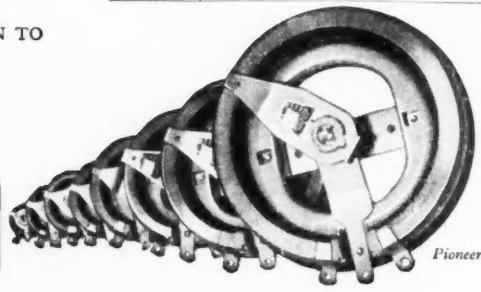

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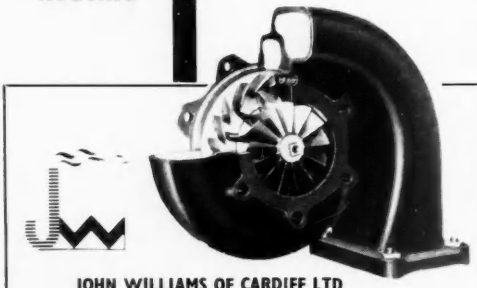

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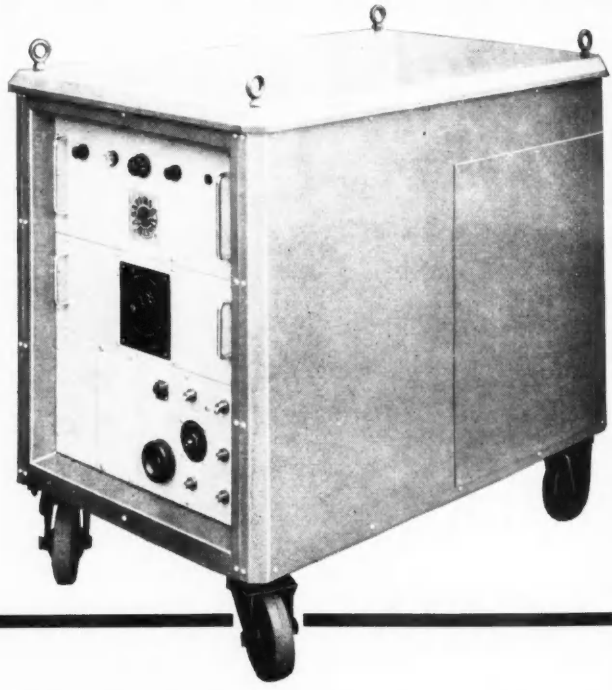

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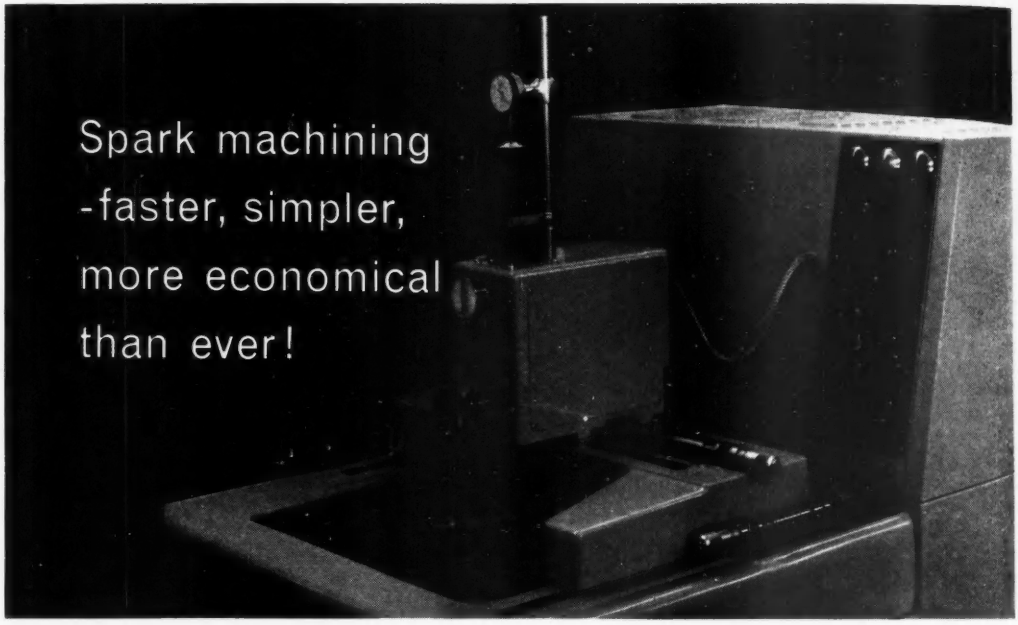

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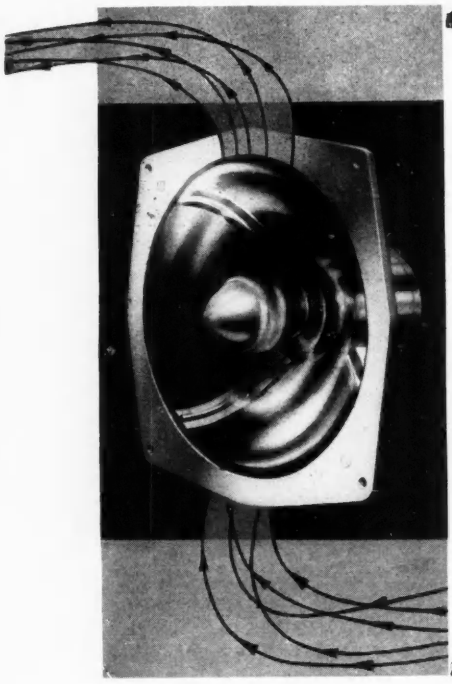

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Elongation	18%	Elongation	5%
Yield Point	12 tons	Yield Point	24 tons
Tensile Strength	25 tons psi	Tensile Strength	35 tons psi

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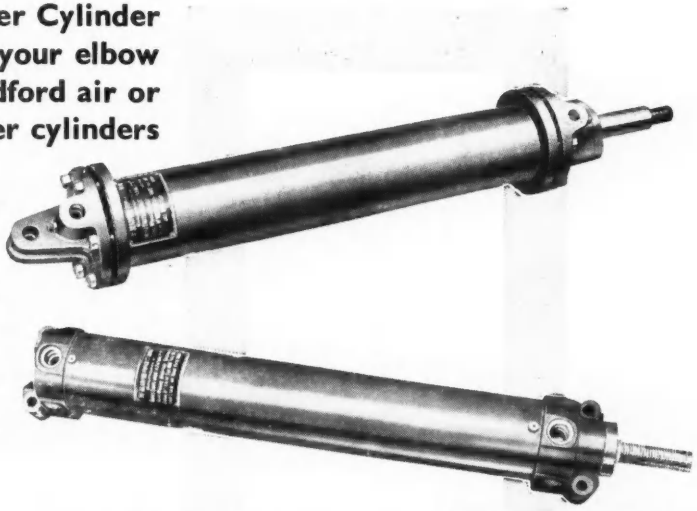

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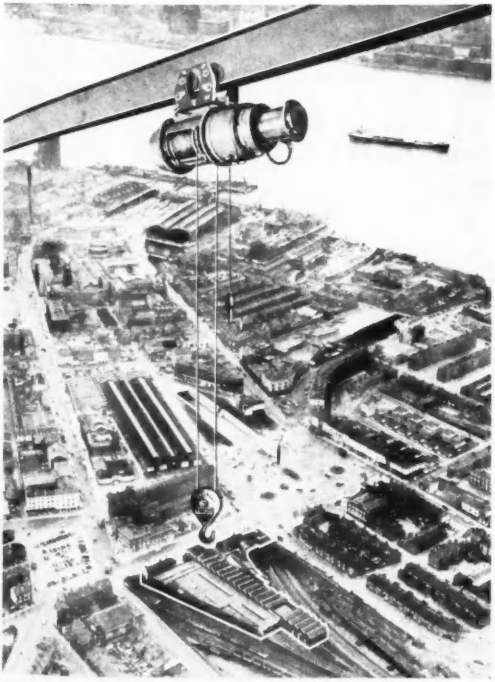

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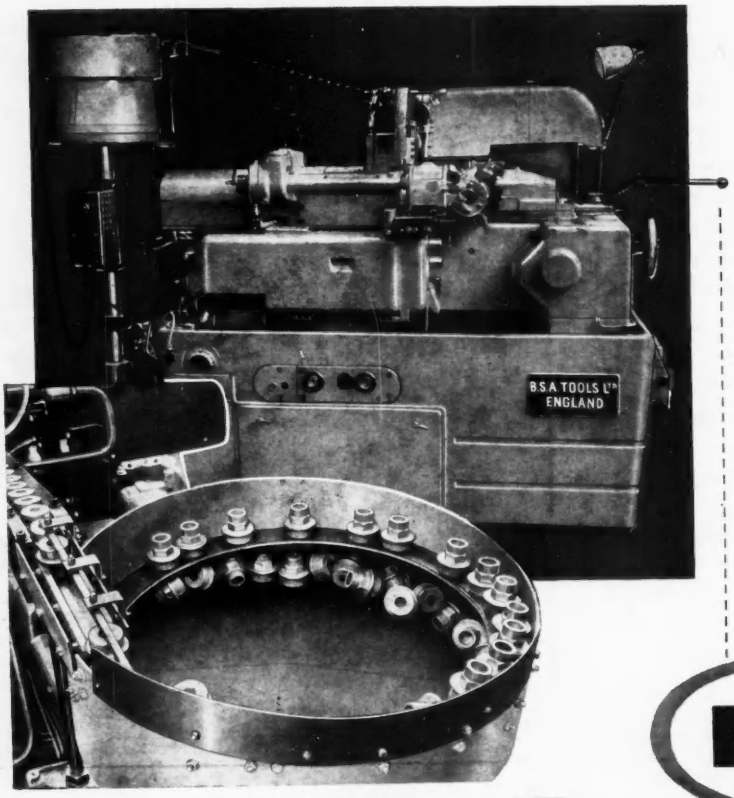
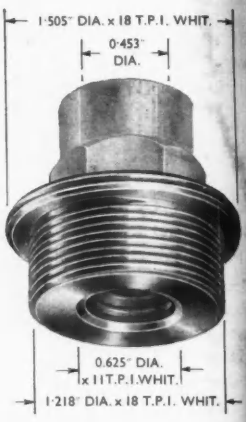




HOT BRASS STAMPING

Countersink. Form and combination drill. Face and Chamfer. External thread (2 diams.) and recess. Tap.

SPINDLE SPEEDS: L.H. 1440 RPM.
R.H. 582 RPM.

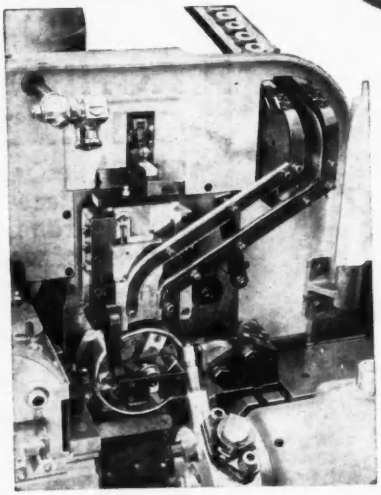
CYCLE TIME: 20 SECONDS.

B·S·A

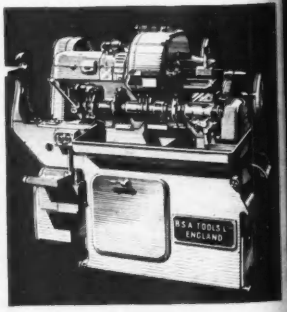
Top: B.S.A. No. 98L automatic arranged to produce the subject component is equipped with pneumatic workspindle-positioning attachment for stopping and locating the spindle with chuck jaws in a position of definite relation to tooling or, as in this example, the component.

Above: Vibratory hopper feeds the components to gravity chute.

Right: Air operated escapement releases components singly to a carrier on the third slide. Component is pushed into the chuck (positioned to receive the hexagon) by a ram in the turret. Thread cutting attachment is on front slide.



single spindle automatics



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